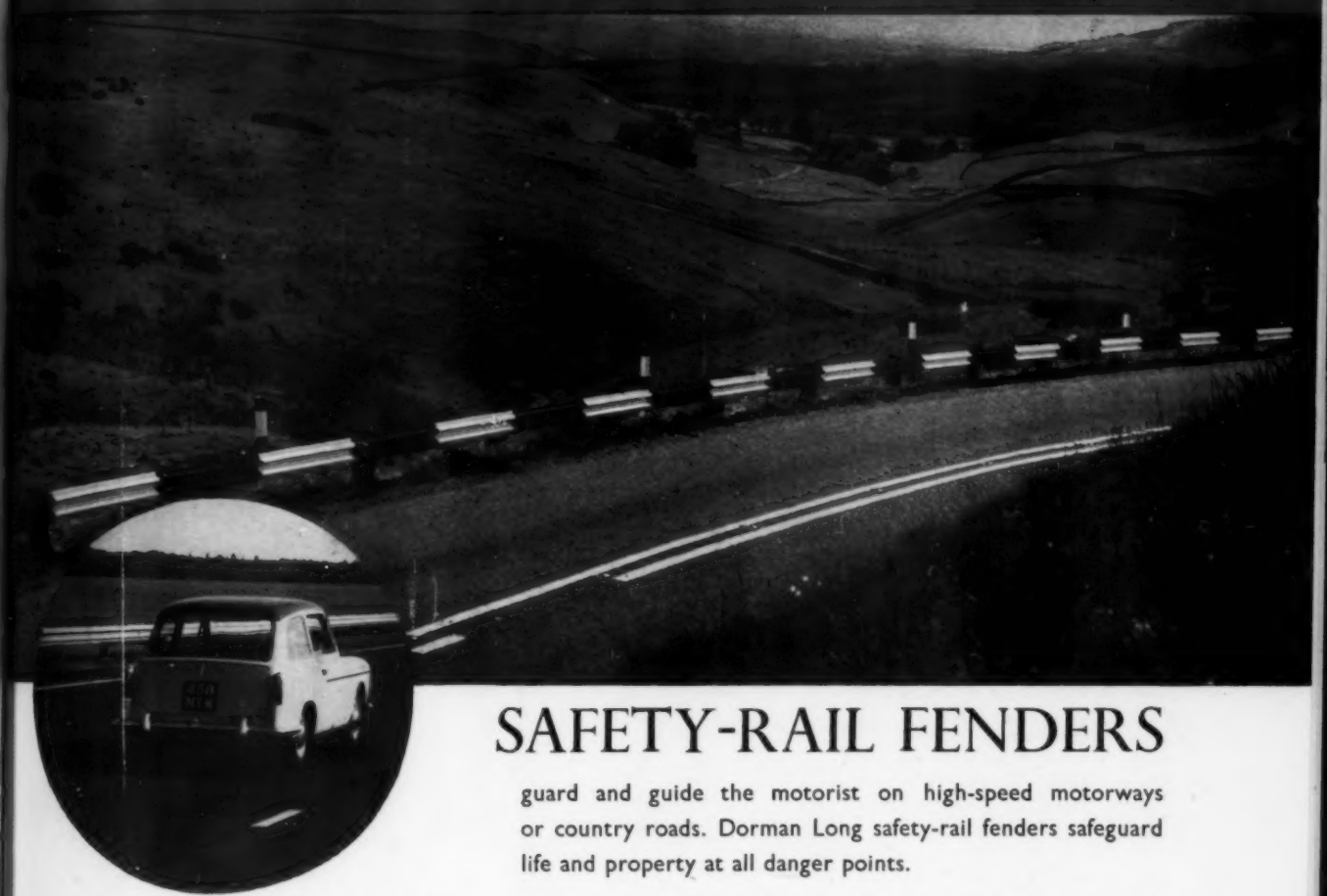
...portation
...brary

TRAFFIC ENGINEERING & CONTROL

...ERSITY
OF ...HIN...
J...
TRANSPORTATION
LIBRARY

Vol. 3, No. 8, December 1961 Annual Subscription £2 2s. 0d. Single copies 3s. 6d. monthly



SAFETY-RAIL FENDERS

guard and guide the motorist on high-speed motorways or country roads. Dorman Long safety-rail fenders safeguard life and property at all danger points.

Inset: Safety-rail fenders erected on the London-Birmingham Motorway. (Photograph by courtesy of John Laing & Son Ltd.)

The top illustration shows safety-rail fenders in position on the A-66 road near Brough. By courtesy of J. McInnes Esq., A.M.I.C.E., County Surveyor, Westmorland.

DORMAN LONG

DORMAN LONG (STEEL) LIMITED, AYRTON ROLLING MILLS, MIDDLESBROUGH

BRANCH OFFICES: LONDON, BELFAST, BIRMINGHAM, BRISTOL, GLASGOW, LEEDS, MANCHESTER, NEWCASTLE and NOTTINGHAM

Illuminated signs in 'Perspex' were chosen for this Liverpool bus station

With their bright, eye-catching colours and clean, clear lettering, these signs in 'Perspex' enhance the appearance of the Ribble Motor Services bus station inside and out. The signs are internally lit by fluorescent tubing, so they can be read easily by day or by night.

'Perspex' is available in a wide range of colours and in clear or opal sheets in various patterns, so you are sure to get exactly the sign you want. 'Perspex' keeps its good looks indefinitely, even when exposed to the toughest weather conditions.

'PERSPEX'

'Perspex' is the registered trade mark for the acrylic sheet manufactured by I.C.I.

P845

IMPERIAL CHEMICAL INDUSTRIES LIMITED LONDON · S.W.1

ICI

The directional signs and the Company sign illustrated here were made from 'Perspex' acrylic sheet by Nightingale Products (Blackburn) Limited, Feniscowles, Blackburn, for the Skelhorne Street, Liverpool, Bus Station of Ribble Motor Services Limited, Preston.

TRAFFIC ENGINEERING & CONTROL

Incorporating TRAFFIC MANAGEMENT

VOLUME 3 No. 8 DECEMBER 1961

The only British monthly devoted exclusively to traffic engineering.

Editor
ERNEST DAVIES

Editorial Advisory Board
SIR WILLIAM G. HOLFORD
SIR WILLIAM BLACK
PROF. W. FISHER CASSIE
WILFRID ANDREWS
CHRISTOPHER T. BRUNNER

Editorial Consultants

Lighting
GRANVILLE BERRY

Parking
CONRAD ANDREN

Signs and Markings
K. SUMMERFIELD

Road Safety
BRIG. R. F. E. STONEY

Industrial News Editor
N. A. KELLY

Advertisement Director
ERIC G. DAVIES

Advertisement Manager
A. G. D. SOAMES

Circulation Manager
E. M. CLARKE

Northern Representative
J. N. ROGERS
24 Ainsdale Drive, Sale,
Cheshire. Tel. Sale 6528.

Traffic Engineering & Control is published by Printerhall Limited, 34-40 Ludgate Hill, London, E.C.4, City 1755/6/7, and printed at The Grange Press, Southwick, Sussex.

The entire contents are protected by copyright in Great Britain and the Universal Copyright Convention, but matter may be reproduced provided that due acknowledgment is made, except for complete articles, in which case application should be made to the Editor.

Annual Subscription £2. 2s. 0d. post free (single copies 3s. 6d.) United States and Canada $7. All other countries £2. 10s. 0d. sterling.

CONTENTS

Editorial Opinion—Data Deficiencies 465

Topics of the Month 467

FEATURES

Chelmsford's O-D Survey—Postcard Traffic Study 468
David C. Reynolds

Driver Behaviour at Traffic Lights—The Critical Amber Period . . 473
A. Crawford and D. H. Taylor

Report from Soviet Russia—Town Traffic Problems . . . 479
A. Stramentov

Significance of Hammersmith Flyover 483
Richard Edmonds

Developments Illustrated 486

Profile—John L. Beckett 488

New Publications 489

Parking Problem Solved in Detroit 490
J. D. McGillis

Research into Highway Traffic Accidents 493
H. J. H. Starks, F. Garwood, G. O. Jeffcoate and R. J. Smeed

Traffic Engineering Group—Practical Traffic Surveys . . . 499
B. L. Allen

Letters to the Editor 501

New Pedestrian Crossing 502

Lighting at Washington Conference—Traffic Engineers Discuss Road Lighting 503
Granville Berry

Industrial News 506

TEC728 for further information

TYPE 54 IN ACTION AT PRESTON

Preston has installed the versatile Type 54 controller to help its traffic problems—severe by any standards. The example illustrated is a two-phase controller on a 'T' junction with heavy turning traffic. Police control was formerly used. Not only is traffic safely and expeditiously circulated but pedestrian interests are also looked after by an ingenious application of the "all red" period. This is variable up to four sec. maximum governed by vehicular density. The pedestrian gets maximum consideration when he needs it most.

Leave nothing to chance on Britain's roads —install "Electro-matic" Type 54.

ELECTRO-MATIC
VEHICLE ACTUATED
ROAD SIGNALS
AT 10401

AUTOMATIC TELEPHONE & ELECTRIC CO. LTD. STROWGER HOUSE, ARUNDEL STREET, LONDON, W.C.2. TEMple Bar 9262

DATA DEFICIENCIES

SPEAKING at the Institute of Transport's Anniversary Luncheon, Dr. Richard Beeching, Chairman of the British Transport Commission, expressed the view that co-ordination of transport had not been achieved because the industry had failed to collect the knowledge without which sensible co-ordination was impossible. If each form of transport be developed so as to have enough but not too much capacity to deal with those traffics which it is best suited to handle, it is necessary first to know what each form of transport can do better than other forms, in terms of quality and cost and second, to obtain a picture of the whole national pattern of transport requirements, to know the characteristics which determine the relative suitability of traffics for one form of transport or another.

It is precisely this, in his particular sphere, that the traffic engineer tries to do. One of his main tasks is the collection of data about the pattern and behaviour of traffic in order to plan and design facilities to meet demand in the best possible way. Whereas in the application of his methods and techniques to the management of traffic he deals with roads exclusively, in this earlier stage of planning and design he must also concern himself with other forms of transport, the use to which they are put and their economics. In its earlier development, traffic engineering tended to be solely engaged in traffic operations but more recently it has become increasingly realized that if the most economic use is to be made of a roads network, it is necessary to take into account the availability and use and economics of all alternative forms of transport. The more recent surveys, such as those conducted in leading American cities, have consequently included the collection and analysis of data on all modes of public transport and analysed it equally comprehensively as that collected on road transport.

Unfortunately, however, this example has as yet not been fully followed here. Traffic studies have been largely confined to studies of traffic volumes, to origin and destination and to road capacities and little or no attention given to the traffics themselves, and the use of transport other than roads. An example of this is the South Wales study. Within its limits this is comprehensive and most valuable in pointing up the deficiencies in the road system of the area, in revealing the extent to which it is already overloaded, and will become increasingly so unless a roads programme far larger than anything yet contemplated is authorized. In view of its importance, it is proposed to describe the methods and techniques employed in its conduct in next month's issue. Its value would, however, have been greater if the consultant engineers entrusted with the task had been required also to consider the transport pattern of the area as a whole, its use and economy. It is to be hoped that the terms of reference for the London Traffic Survey can and will be so interpreted—and the funds made available—to enable full account to be taken of all available public transport facilities, their use and cost, the railways included. Without such information of the travelling habits of the Londoner the roads plan that is finally drawn would be based on inadequate data.

Dr. Beeching is therefore correct in stating that if each form of transport is to be developed so as to have enough but not too much capacity to deal with those traffics which it is best suited to handle, this data must be available. A comprehensive national survey is of course needed because, although the British Railways are now accumulating much data not previously available as to their use and cost, and the Ministry of Transport, together with the Road Research Laboratory, is doing far more it this direction than hitherto, the two are insufficiently co-ordinated and too much is still done on an ad hoc basis.

The highway and traffic engineer, concerned as he is at getting the maximum capacity from the roads out of the expenditure of the limited funds available, is not zealous in attracting maximum traffics to them or those which could better be otherwise carried. On the contrary, his worst headaches often arise from the greater volume of traffic that is generated by the application of his professional skill to their design, construction and management; in fact, it is paradoxical that the greater his success, the worse his headache. It is as much in his interest, as it is of all concerned with other modes of transport, that all available transport capacity be used to the best possible economic advantage—that traffic be spread evenly over all forms in accordance with its suitability and cost as Dr. Beeching desires. How this can be achieved is a matter of national transport policy which is the responsibility of the Government of the day because it is influenced by many factors outside the industry's control, including capital investment and taxation. The traffic engineer in his particular sphere can provide the data to assist in the formulation of policy, and he can implement it within the area of his responsibilities, but he has to work within the limits of policies made by others and of available funds.

Hammersmith Flyover

Consulting Engineer
G. Maunsell & Partners

Engineers
Chief Engineer to LCC
J. Rawlinson, C.B.E., M.I.C.E.
Architect to LCC
H. Bennett, F.R.I.B.A.

CONSTRUCTION BY

Contractors for
POWER STATIONS
DOCK AND HARBOUR WORKS
HYDRO ELECTRIC WORKS
REINFORCED CONCRETE WORKS
RAILWAYS
ROADS
MAIN DRAINAGE

MARPLES, RIDGWAY & PARTNERS LTD.

CIVIL ENGINEERING CONTRACTORS

2 LYGON PLACE, GROSVENOR GARDENS, LONDON, S.W.1.

Telephone: SLOane 0781 Telegrams: Maripar, Sowest, London.

Topics of the Month . . .

IN regard to the centralized administration of transport, the Journal *Etudes Routières* has put forward the suggestion that each country should set up a Ministry of Roads and Traffic so that the organization of road planning and construction, signalization, traffic control and police are brought under a single authority. Our contemporary contends that most ministries are in charge of many functions other than roads, and this results in a scattering of assignments, causing an unsatisfactory administrative organization and inadequacies within the public services in all fields pertaining to road construction and traffic. We have not been hesitant in drawing attention to such deficiencies in this country and unquestionably a single authority for formulating policy is necessary, but it seems to us that if responsibilities of the Ministry of Transport—which has already had civil aviation hived off—were to be further divided and a separate Ministry of Roads and Traffic established, transport would be regarded even less as a whole and there would be less chance of a national policy for all its forms being drawn up and applied. In this country power and responsibility for policy is already concentrated in a single Ministry.

The Transport Bill

THE effect of the Transport Bill, which provides for the abolition of the British Transport Commission, depends on the extent to which its segregated undertakings, transferred to four Boards and a Holding Company, continue to work in co-operation. On the face of it, this further splitting of the system would make for increased and wasteful competition within an industry already possessed of excessive capacity. The Bill, however, provides for the setting up of a Nationalized Transport Advisory Council to advise the Minister on questions relating to nationalized transport undertakings, including co-ordination, composed of the Chairmen of the Boards and the Holding Company and seven members drawn from those experienced in industry, commerce, finance, economic matters, applied science or administration. Since the Minister can himself preside over the Council, and in view of the very wide powers and responsibilities in regard to the undertakings entrusted to him under the Bill, he has the opportunity to achieve a large measure of co-ordination in this limited transport sector. Unfortunately, however, the Council's activities are confined to the nationalized undertakings and for co-ordination to be effective there must be a national transport policy applied to the whole industry.

New Approach to Economic Assessment

IN a thought provoking paper on 'The Economic Justification of Roads' given before the Institution of Highway Engineers, Christopher Brunner made a convincing case for a new approach to the economic assessment of the benefits accruing from road construction. He contended that the conventional methods currently used—the cost benefit basis, for instance,—are inadequate, especially in the under-developed countries. He considers that a number of factors heretofore largely ignored should be taken into account, including enhanced values in terms of development, production and living standards, and their consequent effect on the national income. He instanced that if the deficiencies in road standards linking South Wales and Clydeside with the industrial Midlands were made good, the benefit would not be confined to a reduction in transport costs but would extend to the fuller integration of these areas into the economy of the whole country. In this way he sees road investment as an important means of increasing national income and seeks to find a method of road evaluation based on its expansion, quantifying all the economic and social benefits. Certainly far more research is required in this field of economic assessment, not only of roads but of all transport development and investment. Too much stress is generally put on the tangible results seen to accrue from road construction and insufficient on the intangibles. The modern economist is largely to blame because of his limited approach. His yardstick is too frequently economic return expressed in monetary terms, but an apparent financial loss—even after assessing such known factors as speedier and smoother traffic flow, reduction of accidents, etc.—may be more than compensated by other factors on which no financial value can be placed, such as the loss of convenience or amenity were the facility not available. It is this inability easily to see the real return on road investment that has probably caused investment in roads to lag behind.

Christmas Traffic

LONDON is to have no pink zone this Christmas because many of the restrictions imposed during the previous two Christmas periods have become permanent. Use of the parking meter has been widely extended and a number of traffic engineering schemes have been instituted. Two new one-way systems have been introduced, however—one in the Baker Street-Gloucester Place area for a six months trial and the other in the Piccadilly area for a short period. Whether the Minister is wise to experiment during a period of difficult traffic conditions is questionable; maybe he will learn a lot, but confusion generally develops when the motorist is confronted with changed directional routes to which it takes time to adjust. In regard to additional parking provisions to cater for the extra traffic, which shopping expeditions and visits to the decorations generate, the Minister is providing for temporary parking spaces for 2,000 cars only. This seems a very small contribution to make, and with the parking meter schemes substantially reducing parking spaces previously available, and with few additional off-street parking garages yet constructed, it looks as though congestion will be worse than ever. Mr. Marples might have eased the Christmas shopper's lot more if he had closed to traffic some of the main shopping streets and removed from them the pedestrian-vehicle conflict which is so acute at this time.

Chelmsford's O-D Survey

Fig. 1. The survey in progress.

POSTCARD TRAFFIC STUDY

David C. Reynolds, *A.M.I.C.E., A.M.I.Mun.E.*

The special reasons why the Borough of Chelmsford conducted its O - D survey by postcard are given by the Senior Assistant Engineer and the unique method employed is described.

THE traffic problem in Chelmsford is acute. The Borough is the County town of Essex with a population within its boundaries of about 50,000, but with at least half this number again in the area immediately surrounding the town and with a considerable pull from outlying districts. A population approaching 80,000 is served.

The town centre is at the intersection of the A414, A130 and A122, and the A12 (London-Colchester Trunk Road) by-passes the centre on the East. Besides being a busy shopping and business area, the town centre contains the main railway and bus stations and is bounded immediately to the north by two large factories, which together employ over 10,000 people. The layout of the Town Centre is shown on Fig. 2.

Despite the system of one-way streets that has been introduced, traffic delays and hold-ups are a regular occurrence during the morning and evening peak hours and the congestion is such that partial paralysis of movement is not uncommon.

The quinquennial review of the Town Map occurs in 1961 and besides this, plans for the extensive redevelopment of the Central Area are in the course of preparation.

Purpose of Survey

The Survey's overall purpose was to define the traffic movements in the town centre and to provide sufficient information so that both inner and outer relief road systems could be planned.

The more specific initial needs were:

(i) To establish routes and priorities for inner relief roads.
(ii) To define widths of such roads.
(iii) To indicate types of junctions suitable.
(iv) To show possible routes for cycle tracks.
(v) To indicate possible town by-pass roads.

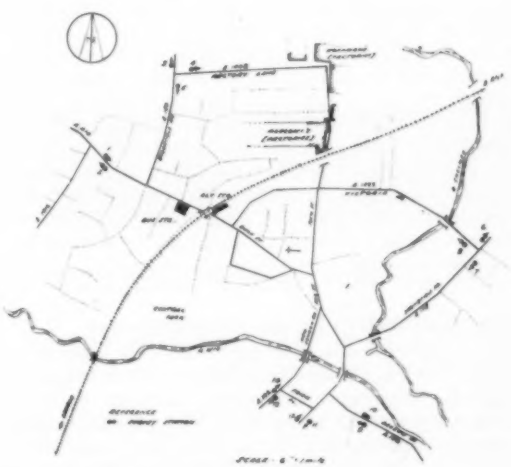


Fig. 2. Town Centre and survey stations.

There is a considerable volume of cycle traffic in Chelmsford and existing cycle tracks are very well used.

Choice of Method

The enclosure to the Ministry of Transport Circular 612 suggests four methods for carrying out origin and destination surveys as follows:

(i) By direct interview.
(ii) By observation of registration numbers.
(iii) By use of postcards.
(iv) By tags on vehicles.

The postcard method was considered as being most applicable to Chelmsford's case as it offered these advantages over the other methods:

(i) Although direct interviews can doubtless provide the fullest information, the postcard method does not delay the traffic by nearly such an extent. The narrow carriageways and heavy traffic would have made interviewing an impossibility.
(ii) Postcards are relatively easily analysed.
(iii) The origins and destinations of vehicles are not obtained by the registration number or tags on vehicles methods, except within the limits of the survey stations. The information from postcards can be such that its application is not limited to the area within the survey stations.
(iv) The registration number method is not applicable to pedal cyclists.

Postcard surveys have the disadvantage that because of postage the cost is relatively high. There is also uncertainty as to what percentage will be returned; a return of 20 per cent has been quoted as the minimum required to make analysis possible.

There were several local factors in Chelmsford which made the prepaid postcard method the most applicable. For instance, the road pattern in Chelmsford's centre is such that with the information that could be gained from the postcards, coupled with the survey stations planned, it is relatively simple to trace the routes taken by traffic through the town. Further to this, the punched card machines operated by the Council are particularly suitable for sorting the postcards.

Postcards

The wording on the postcards was considered most important. It had to be unambiguous and concise, but at the same time had to provide sufficient information so that the driver's route could be plotted through the town and his journey reassigned as necessary to the relief system. The card finally selected for use is shown in Fig. 3 and it will be seen that the driver had to answer four questions. It was felt necessary to state on the card where and when the card had been issued, so that drivers who had collected several cards during the survey knew to which journey each card related.

The card as such proved to be very successful, except that in a number of cases the answers to the first two questions were reversed—a point which was easily noticed and corrected during analysis when checked against the issuing station. White cards were used for motor vehicles and green cards for pedal cycles.

A series of counts was undertaken to establish the number of cards required and the printer delivered these in separate packets for each station and survey hour. The Postmaster issued the licence required for the business reply service after he had approved the printer's proofs of the postcards.

BOROUGH OF CHELMSFORD

You know the traffic difficulties in Chelmsford We are trying to solve them. PLEASE HELP by filling in this card about your journey and posting it. No stamp is required. **No 26**

Where had you come from today? *Town/Village* .....
Street .....

Where were you going today? *Town/Village* .....
Street .....

This card was handed to you between 5 p.m. and 6 p.m. at NEW LONDON ROAD on Friday.

Did your journey involve a call in Chelmsford? YES/NO

If yes, name of Street or Works .....

PLEASE COMPLETE EVERY CARD HANDED TO YOU

FOR OFFICIAL USE

Day	Time	Station	Origin	Destination		
2	4	13				

Fig. 3. The postcard used for the survey.

Stations and Times

Fourteen survey stations were selected and these are shown on Fig. 2. Apart from the Rectory Lane and Victoria Road stations which dealt with East bound and West bound traffic respectively, the remaining stations were sited to deal with the traffic moving in each direction on each road. The siting of the stations was such that no traffic could enter or leave the town centre without passing a station.

The days chosen for the survey were Tuesday, Friday and Saturday of two consecutive weeks: Tuesday as it represents a normal week-day, Friday being market day, and Saturday as the peak shopping day. The hours covered were:

8.0 a.m. to 9.0 a.m. — the morning movement of traffic to places of work.
10.0 a.m. to 11.0 a.m. — the normal business period.
12 noon to 1.0 p.m. — movements to and from places of work.
5.0 p.m. to 6.0 p.m. — the evening homeward peak hour.

Seven stations were manned during the first week, and the remaining seven on the following week and these were chosen so that, as far as possible, vehicles would only receive one card on one journey.

Publicity

As mentioned previously, a census by prepared postcards suffers from the uncertainty of the public's co-operation. It was therefore felt that publicity was of prime importance both before and during the survey and in this respect local newspapers co-operated fully. The Council inserted notices in them during the two weeks prior to the survey briefly drawing the public's attention to it and its aims, and asking for co-operation. The press followed up these notices with editorials and articles which it was felt did much to make the public census minded. During the survey itself, the newspapers printed pictures and further articles on the progress of the survey and urged those who had received postcards to complete and return them.

Personnel

The Council temporarily employed people to hand out the postcards at each station (they will be called 'enumerators' for lack of a better name). Several of those employed were retired police officers who, it was felt, would be used to dealing with traffic. Two enumerators were appointed to each station, one to hand cards to motor vehicles and the other to pedal cyclists. Each station, or group of stations, was under the supervision of a senior member of the Borough Engineer's staff, the junior members of which were available to assist in the handing out of cards at peak hours. Two police officers were on duty at each station to direct and control the traffic, it being emphasized in the written instructions to enumerators that it was not their responsibility to stop or direct the traffic.

Operation of the Survey

Between 7.30 a.m. and 7.50 a.m., the survey equipment for each day was delivered to each station, the enumerators having had instructions to be present by 7.30 a.m. This equipment consisted of the following:

2 No. Traffic Census signs mounted on eight wood posts.
1 No. Box containing eight envelopes, one for each survey hour, for both pedal cycles and motor vehicles.
2 No. Red Flags.
2 No. Red Lamps.

This equipment was kept as light as possible so that stations could be set up or removed with the least possible delay. Fig. 4 shows the ideal layout of a station. It is called ideal because it was found that where road conditions allowed the station to be so set up, there was the least delay to traffic and the highest capacity for issuing cards was achieved.

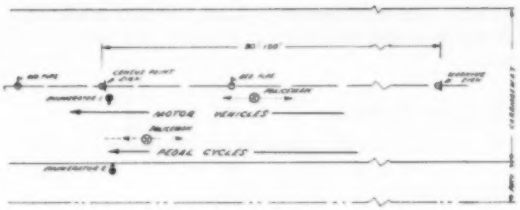


Fig. 4. Ideal layout for survey station.

Enumerators were instructed to issue cards for the precise hour to every vehicle driver and pedal cyclist and any lost time was to be carefully noted. They recorded the number of cards issued by reference to the serial numbers on the cards and also recorded the number of cards refused, of which there were very few. All records and returns were made on a form on the front of the envelope from which the cards were issued and these were collected with the rest of the equipment at the end of the day. In one or two cases, the traffic built up to such an extent that the police had to close the station for a short time, but in all but one case, this was solved by doubling up on the enumerators.

The highest number of postcards issued in one hour by one enumerator was 685 to pedal cyclists; 550 was the highest number handed to motor vehicle drivers. These figures can possibly be treated as a maximum as the station layout in these cases was ideal. When the enumerators were doubled, 800 cards was the maximum handed to motor vehicle drivers and 790 to pedal cyclists. In the latter case, however, it is probable that the two enumerators could have handed out more than this without trouble. The highest hourly flow in one direction recorded was 791 motor vehicles and 1339 pedal cycles. However, the layout of the station was such that the station had

Fig. 5. Zones for motor vehicles.

Fig. 6. Zones for pedal cycles.

to be closed several times to ease the congestion. Generally speaking, it was found that vehicles, and more particularly, pedal cycles, did not need to stop when cards were handed to their drivers. This very much helped to prevent congestion.

During the six days of the survey, there was only one wet day, and fortunately it was not sufficiently wet to cancel the survey. This wet day considerably reduced the number of pedal cyclists on the road, but since it was a Saturday, a day on which there are far fewer cyclists than a normal working day, the loss did not adversely affect the analysis. The Eastern National Omnibus Company co-operated most fully by sending a complete list of their services for each survey hour. It was thus not necessary to hand postcards to the bus drivers as origins and destinations could be coded directly.

Supplementary Information

At the same time as the main survey, various straightforward counts were made to assist the subsequent analysis. A series of short counts was also made to establish the proportion between heavy and light vehicles so that flows could be expressed in passenger car units (i.e. 3 p.c.u.'s = 1 heavy vehicle; 1 p.c.u. = 1 light vehicle; ½ p.c.u. = 1 pedal cycle). An almost constant figure of 15 per cent heavy vehicles resulted from these counts.

Returns

In all 88,910 postcards were issued and of these 50,141 were handed to motor vehicle drivers and 30,475 to pedal cyclists. 8.75 per cent of the motor vehicles and 10.25 per cent of the pedal cycles did not receive cards for the following reasons:

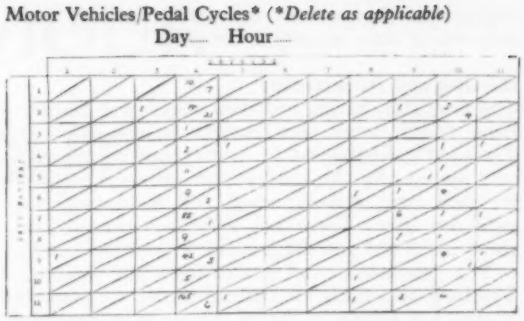
(i) The Police had to close temporarily some stations to ease congestion.
(ii) All available cards for the survey hour were used before the end of the hour in some instances.
(iii) A few people refused to take cards.

Just under 50 per cent of the postcards were completed and returned and in the main the returns for stations varied within 10 per cent of the average. The highest and lowest percentages returns for separate stations were 80 per cent and 29 per cent respectively. As might be expected, the better run, or more ideal stations, gained higher returns, and there was a slight fall off in returns for the later survey days. Not more than 20 or 30 cards contained irrelevant or useless information.

Analysis of Results

The analysis of the returned postcards divided itself into two separate operations. The purpose of the initial analysis was to extract the information from the postcards and arrange it in such a manner that data for the final analysis, which consisted of flow maps, redistribution, etc. were available in a readily obtainable form.

Origin and destination zones, shown on Figs. 4 and 5, were chosen so that they co-ordinated with the Survey stations. For motor vehicles, five zones were chosen within the Borough and west of the A12, and six zones or routes were chosen for origins and destinations outside the Borough or east of the A12. The zones for pedal cycles were all inside the Borough and west of the A12, as it was considered that the small out-of-town flow could be incorporated in an approximate in-town zone. The increased number of zones for pedal cycles was necessary so that industrial areas could be isolated and treated separately.



N.B. Vehicles calling at Town Centre—Fill in top triangular section.
Vehicles NOT calling at Town Centre—Fill in bottom triangular section.

Fig. 7. Analysis chart.

Postal delivery of the cards was made to the Borough Engineer's Department, where on receipt, junior clerks divided them into white motor vehicle cards and green pedal cycle cards. The process for the two types of cards in the remaining stages was kept entirely separate since the respective origin and destination zones for each were different. Two groups of four assistants were employed in zoning the cards. Their task was to select and write the origin and destination code numbers in the spaces left for them in the Official Use section of the postcard. After these numbers had been written, the cards were placed in one of three piles according to their day of issue. This latter operation took very little time and saved one process of the mechanical punched card sorting to follow. Once the assistants engaged on this numbering task had got used to selecting the

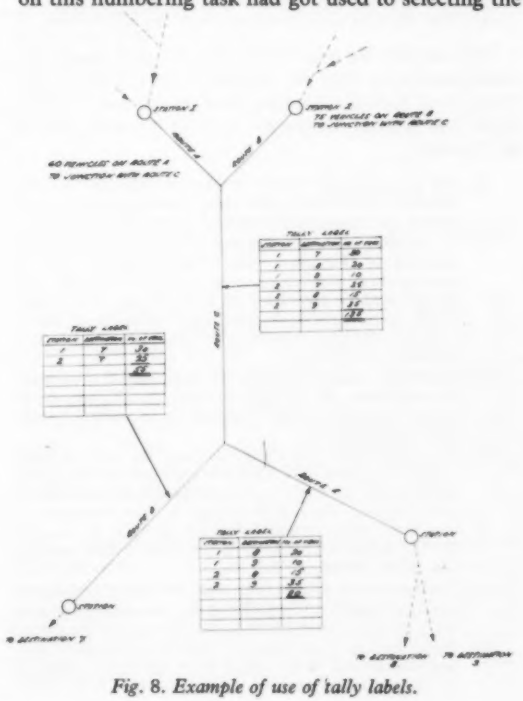


Fig. 8. Example of use of tally labels.

origins and destinations, each card normally took only two or three seconds to complete.

Sorting and Adjustment

The postcards, having had their origins and destinations coded, were then passed to the Borough Treasurer's department for sorting by the punched card system. By this method, groups were isolated for each time, station, origin and destination, for each day issue. There was a further division into those which did and did not call at the town centre.

The presentation of results from the Borough Treasurer was made on analysis sheets, an example of which is shown in Fig. 7. Thus the information from the 44,000 postcards was transferred to 336 of these analysis sheets and it was from these sheets that all information for the final analysis was obtained.

The figures on the analysis sheets were adjusted as necessary for the following:

(i) Part hour distribution of postcards.
(ii) Percentage return of postcards for each survey station at each hour.

The final figures then showed the 100 per cent flow of traffic.

Final Analysis

The presentation of the results of such a traffic survey may be made in several different ways, but basically it is required to show how traffic is distributed within the existing road network and then the effect of reassigning traffic in an improved network. For the purpose of an initial report on the survey, plans of Chelmsford's traffic were prepared to show the following:

(i) The generation of town centre traffic from sources outside the Borough and from outlying districts of the Borough.
(ii) The flow pattern as existing in the town centre.
(iii) The effect of redistributing traffic on relief roads.

The method by which the flow on each road was established may best be explained by the following example of how the existing flow on the town centre roads was plotted for the 8.0 a.m. to 9.0 a.m. period on Tuesday:

(i) All the analysis sheets for motor vehicles for the selected period were taken and the necessary adjustments, as previously described, were then made.
(ii) A 1/2,500 scale line diagram of the principal road network of the town centre was prepared and on each road, or section of road, over which traffic can be different to any other section of that road, tally labels were pasted. A tally label consists of three columns headed station number, destination and number of vehicles.
(iii) From the analysis sheets for each ingoing station, the numbers of vehicles to each destination were traced around the road network by completing each tally label affected.
(iv) On completion of tracing the flows for each ingoing station, the total flow for each road was obtained by totalling up the number of vehicles for the respective tally label as illustrated in Fig. 6. The accuracy of this was then checked from the analysis sheets for the outgoing stations, by a reversal of the method described above.
(v) Traffic whose destination was the town centre, or which originated from this area, was treated separately by distributing flow to and from parking areas.
(vi) Pedal cycles were treated entirely separately and were combined as necessary with the motor vehicles on the final flow maps.

Redistribution plans showing the traffic that would use the various inner relief roads could be prepared without reference to the analysis sheets if the plan with tally labels for the existing flow had already been made. This was because it was a relatively simple operation to extract from the tally labels all traffic that could be diverted to the proposed routes.

Conclusion

It is not within the scope of this article to describe the various details of the specific findings and proposals arising from the Survey, other than to say that it fulfilled its purpose as defined previously. It is felt that the Survey and particularly its analysis as carried out is particularly suitable to an authority which does not wish to employ more than two or three assistants on such works and where quick results are needed. In Chelmsford's case, the report on the survey together with the basic requirements for first stage relief roads was available within four months.

The total cost of the survey was just under £1,000, made up as follows:

Printing of postcards and postage	£740
Employment of personnel	£150
Miscellaneous items (advertisements, transport, etc.)	£100

ACKNOWLEDGMENT

The author would like to express his thanks to the Borough Engineer of Chelmsford, E. P. Allen, A.M.I.C.E., M.I.Mun.E., for his permission to prepare this article.

NEXT MONTH

Traffic Simulation for Urban Areas.
R. BRAIN, Lecturer in Traffic & Highway Engineering, University College, London

Problem of Headlight Glare.
V. J. JEHU and G. HIRST, Road Research Laboratory

Overhead Pedestrian Ways—Traffic Engineering Study Group.
J. W. DARK

The fourth and concluding article in 'Planning Traffic Intersections' based on the late Dr.-Ing. Max-Erich Feuchtinger's last published work and compiled and translated by Arthur Henderson, has been held over unavoidably until the January issue.

DRIVER BEHAVIOUR at TRAFFIC LIGHTS

Critical Amber Period

by **A. Crawford,** *B.Sc., Ph.D., and* **D. H. Taylor,** *B.A.,*
Road Research Laboratory, Department of Scientific and Industrial Research

This paper describes an experimental investigation of the problem of stopping at traffic signals on high-speed roads. When the traffic signal changes from green to amber a driver may be so close to the intersection that he cannot stop within the intervening distance, and at the same time so far away that he cannot clear the intersection before the end of the amber signal when the red signal commences. The distance is then said to be within the 'critical section' of the road for the particular speed of travel. The experiment described here was carried out to examine the reactions of drivers to the change of traffic lights from green to amber and then to red, and also to determine the size and position of the critical section for a range of speeds. One way in which the lights may be retimed to avoid the occurrence of a critical section is described and discussed.

THE test here described took place on a track 4,000 ft. long, laid out on an aircraft runway, with a signal-controlled intersection sited near one end of the track. The arrangement simulated a vehicle-actuated signal at a minor intersection on a high-speed road (Fig. 1). For each test run the lights were green when the driver first saw them, and he had no idea when, if at all, they would change; the duration of the amber period was three seconds. Apparatus constructed for the experiment was functionally divided into three parts, the radio telemetering system, the signal-actuating device, and the system used to obtain and record the experimental results.

Radio telemetering equipment. A radio link transmitted signals to relay-operating devices in the control van. The signals were controlled by switches attached to the accelerator and brake mechanisms and to a small gearbox attached to the speedometer cable which operated once for every 10 ft. travelled by the car.

Signal-actuating device. The amber phase was controlled by a device which could be set by the experimenter to initiate the amber phase at any required distance of the car from the intersection. It consisted of a stepping switch counter driven by the 10 ft. pulses telemetered from the car. It was also used to activate an instrument which recorded the speed of the vehicle over the last 100 ft. before the lights changed.

Recording equipment. The data, which consisted of time-interval measurements, were all recorded simultaneously on separate tracks of a multi-channel magnetic tape recorder (Fig. 2). The recording was replayed into apparatus which produced a typewritten record of each time measurement. The intervals recorded were:

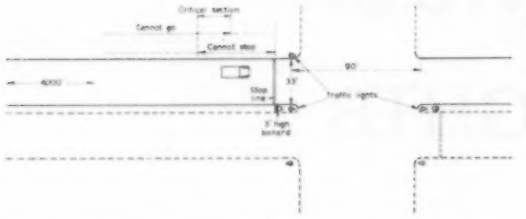


Fig. 1. Plan of the experimental situation. Full lines show layout actually used. (Design as used by Webster, see Ref. 1).

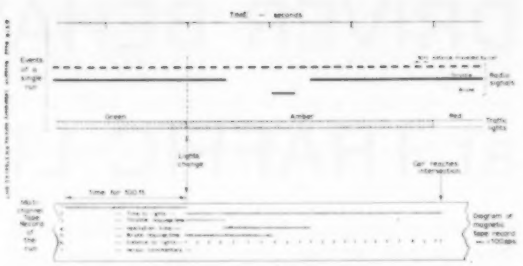


Fig. 2. The record of events during a single run. (The driver changes his mind and decides not to stop).

Channel 1. The time taken to cover the last 100 ft. before the lights turned amber.

Channel 2. The time from the beginning of the amber period to when the car reached a point just before the intersection (as a check on the speed of the non-stopping runs).

Channel 3. The time from the beginning of the amber period to when the driver lifted his foot from the throttle (throttle reaction time).

Channel 4. The time from the beginning of the amber period to when the driver pressed his foot on the brake (brake reaction time).

Channel 5. The time from when the driver lifted his foot from the throttle to when he subsequently depressed it (for runs in which the driver changed his mind).

Channel 6. On this was recorded a pulse for each 10 ft. unit of distance travelled from the beginning of the amber period to the intersection (as a check on the pre-set value for this).

Channel 7. On this was recorded a verbal commentary by the experimenter which gave the weather and surface conditions, the subject, vehicle run number, and speed, together with (*a*) whether the driver stopped, and the violence or otherwise of the action taken, e.g. any tyre squeal or skidding; (*b*) how far from the stop line the car halted or, if it did not stop, where it was when the lights turned red. A similar (written) description was made by the experimenter's assistant sitting as the passenger.

The three cars used for the tests, all of which were driven by all the subjects, were:

1. An 800 cc., four-cylinder saloon with four forward gears and hydraulic brake system.
2. A 2½ litre six-cylinder saloon with three forward gears and hydraulic brake system.
3. A 2½ litre six-cylinder saloon with automatic transmission and power-assisted hydraulic brake system.

The subjects were six men and two women drivers whose average age was about 30 years. Two of them had passed their driving test within the previous year and the remainder had at least three years driving experience. Each subject was tested on three days and drove a different car each day. The order in which the cars were driven was balanced between subjects. On each run the driver was asked to approach the intersection at a speed selected by the experimenter: the speeds were 30, 40, 50 and 60 mile/h. for cars 2 and 3, and 20, 30, 40 and 50 mile/h. for car 1, by the speedometers.

Each run started with the car halted at a line at the far end of the track from the intersection. The speed at which he was to approach the intersection was given to the driver by the experimenter's assistant, who sat as a passenger beside him. He also told the driver when the desired speed had been reached and each time he deviated from it by more than 2 mile/h. The last 1,000 ft. or more before the lights changed were covered at this speed. Only the test car was on the track during any run, and the driver did not have to consider the possibility of being run into by a following vehicle if he stopped suddenly. Nevertheless, he was instructed that all stops made should be comfortable and should not inconvenience his passenger.

Each day's testing consisted of:

(1) A preliminary practice series of 10 runs, including one in which the lights did not change, on the first day of each subject's test, and three runs on the other two days.

(2) A balanced randomized series of 32 runs comprising 28 in which for each of the four speeds of approach for the car being used the lights turned amber at seven different distances from the intersection, and four runs—one at each speed—in which the lights did not change from green.

(3) A series of 20 runs, five at each speed, half of which required easy decisions and the remainder of which covered, in steps of 10 ft. at the lower speeds and 20 ft. at the higher speeds, the range of distances for a given speed from which drivers sometimes stopped and sometimes went on.

The distances from the intersection at which the lights turned amber were chosen so that in at least two runs at each speed the driver did not stop but carried on through the intersection. In all, records of 1,030 runs were obtained of which 650 were stopping runs.

RESULTS

Beginning of the Critical Section

For a given speed of approach, the beginning of the critical section depends on the stopping distance of the vehicle and the driver's response time. As these are not constant values the distance within which drivers can stop on a proportion of occasions must be taken as the measure. In the experiment it was arranged that at some distances all drivers could stop on every occasion they approached at a particular speed; for the same speed other distances were given which were so short that no one tried to stop. Between these two points lay a zone in which drivers sometimes stopped and sometimes did not. The 50 per cent threshold distance is defined as the distance from the intersection from which on 50 per cent of occasions drivers succeeded in stopping without entering the intersection. As the stop line was situated 6 ft. in front of the lights (which were assumed to be on the corners of the intersection) a driver was judged to have stopped successfully if the front of the vehicle was not more than 6 ft. over the stop line, i.e. as he sat in the driving seat the driver was either on or had not reached the stop line.

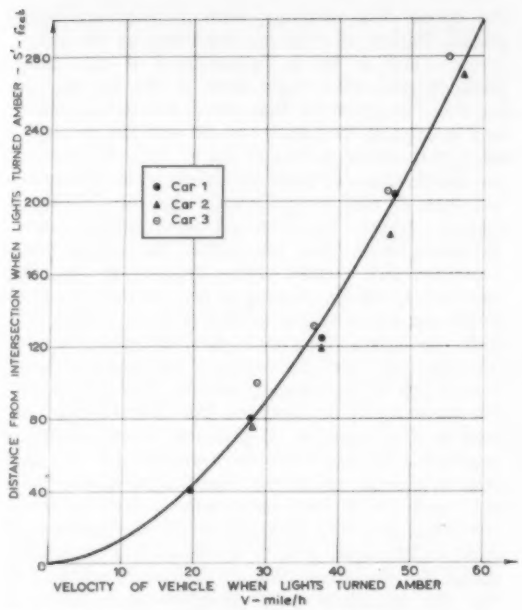

DISTANCE FROM INTERSECTION WHEN LIGHTS TURNED AMBER - S' - feet
Car 1
Car 2
Car 3
VELOCITY OF VEHICLE WHEN LIGHTS TURNED AMBER
V - mile/h

Fig. 3. The 50 per cent stopping threshold distance for three vehicles. S′ is the distance away when the lights turned amber from which drivers stopped (without entering the intersection) on 50 per cent of the occasions. Fitted line has equation $S' = 0.23v^{1.75}$.

The 50 per cent threshold distance (S′) was calculated separately for each speed/vehicle combination (averaged for all the subjects) by an approximate method[1]. Fig. 3 shows the 50 per cent threshold distances for each vehicle at each speed. The differences due to driving the different vehicles was small and it was therefore possible to combine the data for all vehicles and then to apply more accurate methods to obtain the threshold distance at each speed. The proportion of successful stopping runs was plotted against the logarithm of the distance from the intersection at which the lights turned amber, on permille graph paper (which is ruled to produce a straight line for data fitting the normal ogive); a straight line was fitted to the points by eye and the results replotted in Fig. 4. As can be seen, the fit of the data to the log-normal ogive is very close. The series of values of distance (S) for successful stops on 50, 80 and 95 per cent of the occasions, from the data in Fig. 4, has been plotted in Fig. 5. These are called the 50, 80 and 95 per cent thresholds at each speed. From this graph values of S for the

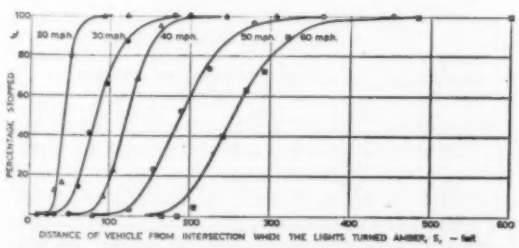


Fig. 4. The proportion of occasions drivers stopped successfully having been at a distance SFT from the intersection when the lights turned amber. (Each curve gives the results for a particular nominal speed of approach i.e. by the speedometer).

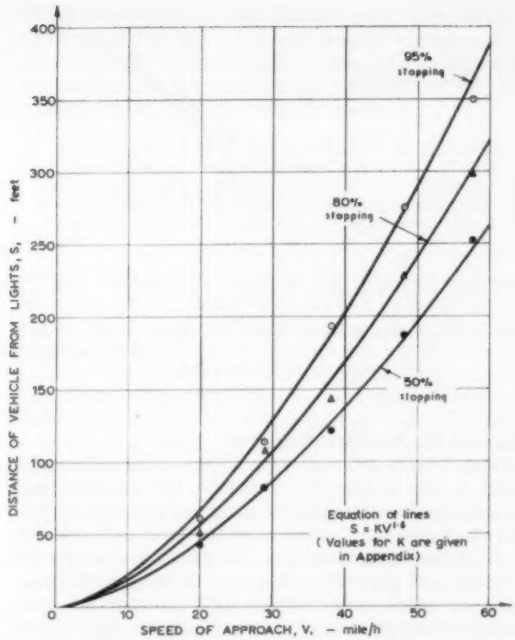

95% stopping
80% stopping
50% stopping
Equation of lines
S = KV^1.6
(Values for K are given in Appendix)
DISTANCE OF VEHICLE FROM LIGHTS, S, - feet
SPEED OF APPROACH, V, - mile/h

Fig. 5. From data of Fig. 4. Distance of car from intersection when the lights turned amber. (Curves give results when on 50, 80 and 95 per cent of occasions vehicles stopped successfully).

speeds of 20, 30, 40, 50 and 60 mile/h. were estimated and are given in Table I, and the equation is given in the Appendix (Equation 5). The provisional results of an independent experiment[2] are substantially in agreement with the data in Table 1.

Analysis of the Stopping Runs

The distances given above are made up of the distance travelled during the foot movements from throttle to brake, plus the actual braking distance. The latter will depend upon the deceleration that the driver can achieve or is willing to attempt; both the deceleration attempted and the response time will depend upon the 'difficulty' of the action required as the driver sees it. The average brake reaction time is reduced to 0.81 second and the average deceleration rises to 0.54 *g* as the interval available in which to stop is reduced to values in which some drivers preferred not to stop.

TABLE I

Beginning of the critical section: distance of vehicle from the intersection when the lights turned amber for three proportions of successful stops from five speeds. (data from Figs 4 and 5).

Speed of approach (mile/h.)	*Distance of vehicle from lights (ft.)*		
	Proportion of successful stops		
	50 per cent	*80 per cent*	*95 per cent*
20	47	58	70
30	90	111	134
40	143	175	213
50	204	250	304
60	273	335	407

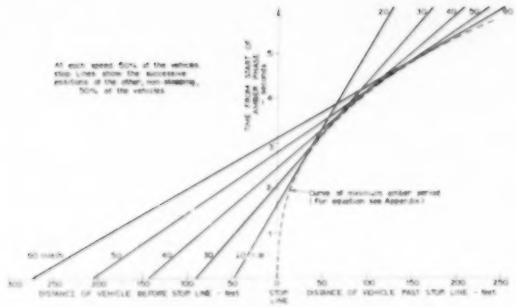


Fig. 6. Successive positions, during the amber period, of cars which are 50 per cent threshold distance from the intersection when the lights turn amber.

End of the Critical Section

When drivers did not stop, if they were sufficiently near to the lights and travelling fast enough they cleared the intersection before the red signal appeared. At some distance further from the intersection is the end of the critical section. Its position depends on the speed of approach, the length of the amber phase, and on what constitutes a safe distance to have reached beyond the stop line when the lights turn red (entry distance).

Table II gives, for a 3-second amber phase, the position of the end of the critical section for each of the five speeds and for four entry distances, calculated on the assumption that the average speed of travel in a run is in fact the speed required by the experimenter for that run.

From the foregoing it will be seen that since the beginning of the critical section is given by the equation $S = KV^{1\cdot6}$ (Fig. 5) its length C will be obtained by the positive values of

$$C = KV^{1\cdot6} - \frac{22}{5}V + E \text{ ft.}$$

(where V is approach speed in mile/h., K takes the values given in the Appendix, and E ft. is the desired distance over the stop line before the red phase commences).

DISCUSSION

It appeared that in this experiment all subjects regarded their task as one of stopping without undue deceleration, and paid little attention to the consequences of decisions not to stop. It would follow from this that the driver's decision to stop was independent of the length of the amber phase. This conclusion is supported by an observational experiment by Olsen & Rothery[3].

On the basis of the 50 per cent threshold distances given in Table I the positions of the cars which did not stop are plotted in Fig. 6 as functions of the time from the beginning of the amber phase. (The cars are assumed to have continued travelling at the same speeds as before the signals changed). These data illustrate the way in which the length of the amber period required to enable drivers to clear the intersection varies with the width of the intersection and the speed. For instance, with a 3-second amber phase, drivers of vehicles travelling at 30 mile/h. would clear a 45 ft. intersection if the amber phase started when they were at the 50 per cent threshold distance for that speed, but drivers travelling at 20 and 40 mile/h. would just fail to clear it when the amber period began at their 50 per cent threshold distances from the intersection. For speeds less than 20 mile/h. and greater than 40 mile/h. the distance drivers still have to travel before clearing the intersection after the end of the amber phase would be still greater. Thus there is an optimum approach speed for clearing an intersection of a given width during an amber period of fixed length. The wider the intersection the higher the optimum speed (see Appendix) and the narrower the range of speeds to each side of the optimum which is also satisfactory. For very narrow intersections the critical section will tend to disappear for all practical lowest speeds of approach. However if the intersection is more than 50 ft. wide, no matter what the speed, no vehicle will travel the 50 per cent threshold distance for its speed and clear the intersection in three seconds; for these widths there will be a critical section at every speed. For an intersection 25 ft. wide it will be seen that the optimum speed of approach is about 20 mile/h. and critical sections will occur for approach speeds of 50 mile/h. and above. This can also be seen by comparing the first columns of Tables I and II. The critical section for a 25 ft. wide intersection (and the 50 per cent threshold) will not exist for 20, 30 and 40 mile/h., it will be 9 ft. long at 50 mile/h. and 34 ft. at 60 mile/h.

It is also seen from Fig. 6 that there is a minimum amber period for a given width of intersection; in a period less than this even vehicles approaching at the optimum speed cannot clear the intersection before the red signal. The minimum amber period is shown in Fig. 6 as a dotted curve. For wide intersections the higher speeds are tangential to this curve, i.e., they are optimum speeds, whereas for narrow intersections it is the lowest speeds which are tangential. Curves of the minimum amber period have been drawn in Fig. 7 for the 50 per cent, 20 per cent and 5 per cent of occasions when drivers did not or could not stop from the distances given in Table I. These show that for all but the narrowest intersections the 3-second amber phase on a high-speed road is too short.

TABLE II

End of the critical section: distance of vehicle from the intersection when the lights turned amber for five speeds and four entry distances

Speed of approach (mile/h.)	*Distance of vehicle from lights (ft.)*			
	Safe distance beyond stop line when lights turn red			
	25 ft.	*50 ft.*	*75 ft.*	*100 ft.*
20	63	38	13	—12
30	107	82	57	32
40	151	126	101	76
50	195	170	145	120
60	239	214	189	164

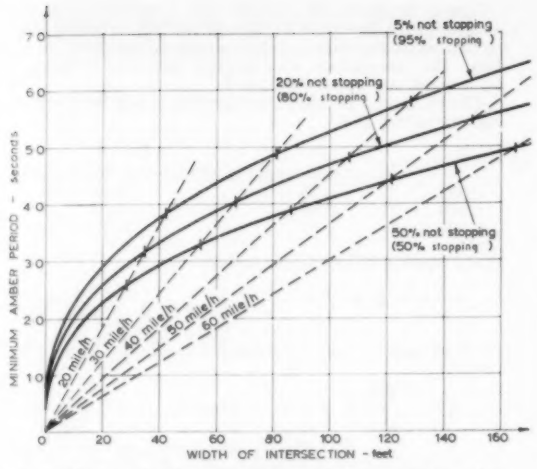


Fig. 7. Curves of minimum amber period commencing when cars were such distances away that on 5, 20 and 50 per cent of occasions drivers did not stop. (For equations see Appendix). Intersection of curves and dotted lines indicate position where speed marked is optimum. (The optimum speed is the speed of approach which for a given amber period will get the driver furthest through the intersection).

On the assumption that if a vehicle has crossed just 25 ft. of the intersection by the end of the amber phase the risk of collision is negligible then, as above, 3 seconds might be long enough for approach speeds up to nearly 50 mile/h. However, for an intersection 50 ft. wide the car will have cleared only half of the intersection when it loses right of way. As it has become common for drivers to start moving forward during the red + amber phase, the choice of 25 ft. might well result in accidents or traffic jams in wide intersections. It is therefore suggested that it would be more realistic to use a figure corresponding to about two-thirds of the actual distance across the intersection and that this should be the minimum distance used as a basis for calculating the length of the amber period.

It has been suggested[2] that a roadside computer which holds the green period would prevent faster vehicles being caught on the intersection in the red phase. On the basis of the present work the alternative of choosing an amber period long enough to suit the intersection merits consideration. On the basis of the average speed of the vehicles on the road and the effective width of the intersection (two-thirds of the actual width), the minimum length of the amber phase necessary can be read from Fig. 7 or calculated from the equation:

$$A = 0.682 \left\{ \frac{I}{V} + kV^{3/5} \right\} \text{ seconds}$$

(Equation 7, Appendix), where A seconds is the amber period, I ft. is the effective intersection width, V is the average approach speed in mile/h., and K is a constant determined by the proportion of occasions on which it is desired that drivers should be able either to stop or to clear the intersection. Reasons will be given later for adopting the value for K corresponding to 95 per cent stopping. When, as is usually the case, a range of speeds has to be allowed for, the procedure is only slightly more complicated, since either the upper or lower limit of the range will determine A. This can be ascertained by solving the above equation for both speeds, or alternatively, by substituting in the following inequality:

> Drivers travelling at the upper limit of speed range require the longest amber period if $KV^{1.6} < 1.67\ I$ (V is the average speed of approach). If the inequality is reversed it is the lowest limit of the speed range which should be substituted in the equation from which A is found.

The relationships between the variables and the derivation of this inequality are given in detail in the Appendix together with a worked example to illustrate the procedure.

In a recent study[4] which has appeared since the completion of this investigation, the authors make a theoretical analysis of what they call the dilemma zone which is similar in form to that presented here. The assumptions made in the study are largely confirmed by the results of the present experiment.

From the driver's point of view, there is considerable advantage in keeping constant as many of the features of the roads as possible, and there may, therefore, be disadvantages in varying the amber period to suit the intersection. Whether or not the amber period of constant length is helpful to the driver depends upon how he tries to use it, i.e. on his orientation to the task as he approaches the intersection. There is considerable 'reward' to many drivers in not being held up at an intersection, and if drivers are going to try to get through on the amber they need to know exactly how long they have or serious risks may be taken. It has often been contended, without proof, that drivers would tend to regard long amber periods as extensions of the green, and that they would be tempted to continue when with a shorter amber period they would have stopped. An observational experiment carried out by Olsen and Rothery[3] to examine this theory showed that the length of the amber period did not affect what has been described earlier in this paper as the threshold. They studied pairs of intersections which were as similar as possible in their physical characteristics but differed appreciably in the length of the amber period. For instance, intersections on roads with a 40 mile/h. speed limit had amber periods of 4.15 and 2.9 seconds and mean approach speeds of 38.0 mile/h. and 36.4 mile/h. respectively during the green period. For intersections on roads with a 25 mile/h. speed limit and actual mean speeds of 32.9 and 31.0 mile/h. the amber periods were 4.75 and 3.00 seconds respectively. It would appear, therefore, that the removal of situations in which it is impossible to clear the intersection before the lights turn red would more than compensate for the loss of a constant amber period.

In practice a constant amber period could be adopted in all situations by making it long enough, or by extending the use of the all-red phase. In the first case the equations given in the Appendix indicate that 5½ seconds would be satisfactory (as defined in the next paragraph) at speeds between 20 and 50 mile/h., for all roads with intersections of up to 100 ft. or less. In the second case, a 3-second amber period would be followed by an all-red phase long enough to allow time for all vehicles to clear the intersection. The length of the amber plus all-red

period would be calculated as for the amber period in the manner suggested above, and by subtracting three seconds for the amber period the length of the all-red phase would be arrived at.

A satisfactory amber period (or amber plus all-red) would be one in which drivers who cannot stop comfortably with a moderate deceleration have time to clear the intersection. It is suggested that the 95 per cent threshold distance should be used as a basis for the design calculation (in the choice of value for K in the equations) to meet this requirement. If, for example, the 50 per cent threshold distance were used in the calculations, the number of drivers who would wish to continue rather than stop from a greater distance would be considerable, and these drivers, by continuing, would fail to clear the intersection before losing right of way. It is desirable to reduce the numbers of drivers who might find themselves in this situation as much as possible and this may be done by using the 95 per cent threshold distances in the calculations, thus eliminating the critical section for a high proportion of drivers.

Of the decisions to stop from the 95 per cent threshold less than 1 per cent resulted in errors, hesitation etc., and the average deceleration from this distance was of the order of 0.4 *g*. With this design-constant the amber period would be long enough to enable drivers who decide not to stop from this or any shorter distance, to clear the intersection. There is no way of accounting for those drivers who decide to stop even though the distance to the stop line is too short, nor for the very small proportion who decide to go on even though 95 per cent or more would stop from the distance; however, with this design there would at least be a safe alternative for them.

APPENDIX

A vehicle travelling at a speed V, at a distance S from a traffic light which turns amber will be able to stop on a proportion P of occasions. The relationship between these quantities was found to be given by

$$S = KV^n \quad \ldots\ldots\ldots\ldots \quad (1)$$

where n and K are constants (K changes with P). (I—P) X 100 per cent of the runs will be 'non-stopping' and the distance (I) travelled into the intersection A seconds later will be: VA—S

where A is the amber period and on the assumption that the drivers continue travelling at the approach speed. So the optimum width of intersection will be given by

$$I = VA—S = VA - KV^n \quad \ldots\ldots\ldots (2)$$

Thus

$$A = (I + KV^n)\frac{1}{V} \text{ which is plotted in Fig. 6 for } n = 1.6 \ldots (3)$$

To find the optimum velocity for a minimum amber period (referring to Fig. 6):

$$\frac{dA}{dV} = -\frac{I}{V^2} + K(n-1)\,V^{n-2} = 0$$

$$\text{or } I = K(n-1)\,V^n$$

$$\text{and } V\,(\text{opt}) = \left\{\frac{I}{K(n-1)}\right\}^{\frac{1}{n}} \quad \ldots\ldots\ldots (4)$$

Substituting for V in (2),

$$A\,(\text{min}) = I^{\frac{n-1}{n}} \cdot K^{\frac{1}{n}} \cdot n(n-1)^{\frac{-(n-1)}{n}} \quad \ldots (5)$$

Curves fitted to the data in Fig. 5 assume that n is constant with respect to P. This is supported by the close agreement of the slopes of the regression lines fitted to the data. The assumption also implies that the variance of log S is not correlated with log S.

The parameter K takes the following values for the three relevant values of P:

K	P (Proportion stopping)	1 — P (Proportion not stopping)
0.581	0.95	0.05
0.479	0.80	0.20
0.390	0.50	0.50

in the equations (1), (3), (4) and (5)

$$\text{i.e. } S = K\,V^{1.6} \text{ ft} \quad \ldots\ldots\ldots\ldots (6) \text{ plotted in Fig. 5}$$

(V is in mile/h. and the necessary coefficient is included in K).

$$A = \frac{0.682}{V}(I + KV^{1.6}) \text{ seconds} \quad \ldots (7) \text{ plotted in Fig. 6}$$

$$V\,(\text{opt}) = 1.38\left[\frac{I}{K}\right]^{\frac{1}{3}} \text{ mile/h.} \quad \ldots\ldots (8) \text{ shown in Fig. 7}$$

$$A\,(\text{min}) = 1.32\,I^{\frac{1}{3}} \cdot K^{\frac{1}{3}} \text{ seconds} \quad \ldots\ldots (9) \text{ plotted in Figs. 6 \& 7}$$

One equation linking V (opt) with A (min) is

$$V\,(\text{opt}) = 0.865\frac{A(\text{min})^{4/3}}{K} \text{ mile/h.} \quad \ldots (10)$$

The product of equations (8) and (9) gives

$$I = 0.55\,A\,(\text{min}) \cdot V\,(\text{opt}) \quad \ldots\ldots\ldots (11) \text{ plotted in Fig. 7}$$

If the lights change to amber before a driver reaches S (for a given P) then there will be a better than P chance of his being able to stop. If they change at S then there will be a P chance of stopping and a maximum penetration into the intersection if the driver decides not to stop. If the amber appears after S, then, though there will be less than P likelihood of stopping, the distance travelled across the intersection before the red will be greater than when the lights change at S should he decide not to stop.

Equation (8) implies that if a driver knows the amber period but not the width of the intersection (as is usually the case on a strange road) and if he has no idea of when, if ever, the amber signal will appear, he can choose his speed of approach for maximum safety.

The application of Equation (7)

In fixing the amber period necessary for an intersection of width I ft. on a road on which the traffic has a mean speed of V mile/h. and range of speeds of from V — δV to V + δV mile/h., it is desirable to test whether the upper or lower end of the speed range requires the longest amber period.

The amber period is given by Equation (7), e.g.

$$A = \frac{0.682}{V}(I + KV^{1.6})$$

It is required to know whether A is increasing over a small range to each side of V. This will be given by the slope of the tangent to the curve at V as before:

$$\frac{dA}{dV} = 0.682\left\{-\frac{I}{V^2} + 0.6\,KV^{-0.4}\right\}$$

$$= \frac{0.682}{V}\left\{-\frac{I}{V} + 0.6\,KV^{0.6}\right\}$$

If A is increasing

$$\frac{I}{V} < 0.6\,KV^{0.6}$$

or

$$\frac{I}{0.6} < KV^{1.6} \quad \ldots\ldots\ldots\ldots\ldots (12)$$

(*Concluded on page* 482).

TOWN TRAFFIC PROBLEMS

By A. Stramentov

Associate Member of the Academy of Construction and Architecture, USSR, Doctor of Technical Science

Fig. 1. Moscow traffic tunnel.

THE territorial growth of towns in the USSR, originating from the vast scale construction of housing, calls for continuous development in the mobility of the population and the means of transport. Consequently the rational organization of transport, quickly and safely, is one of the main problems of the Soviet town planning.

In solving this problem the working basis is not so much the distance of a journey, as the question of time spent in covering this distance. Increasing time on travel means tiredness, so-called 'transport tiredness', which appears as a not unimportant factor confronting all commuters.

The result of additional journey time varies. The prolongation of a workers time after his work officially ends, measured in extra hours necessary for sleep, travelling time dependent on distance of work from place of domicile and condition of travel—such waste of time has physiological effects. A prolonged journey shows a serious unproductive loss of time. Mechanical transport certainly lengthens the healthy working hours by making use of the worker's time more rational. Quickening a journey, eliminating traffic holdups, the reasonable organization of pedestrians, and transport, all save considerable time for urban dwellers.

The problem of a convenient transport network in a new town is resolved in the USSR after consideration of all the complex aspects of town planning.

Table I gives the existing characteristics and prospective development of public transport in towns of the USSR.

On January 1, 1961 there were tramway services in 105 towns, trollybuses in 49, buses in 1,120 and underground services in three.

Well organized systems of public transport to outlying districts limit the development of light motor traffic, especially in the centres of towns. As a rule, in USSR cities, passenger municipal service is given preference over all other transport. It follows, that when this is applicable to contemporary high speed traffic, a town's unity is preserved even to its outlying districts.

The way and degree of expected development of light motor vehicle traffic in towns of the USSR has become especially important, and is connected in the

TABLE I

Proportion of Passengers carried by different forms of Municipal Transport in Towns of the USSR

Method of Transport	*Actual No. of Passengers*						*Prospective No. of Passengers*			
	1940		1946		1958		1965		1975-80	
	Million Passengers	%	*Million Passengers*	%	*Million Passengers*	%	*Million Passengers*	%	*Million Passengers*	%
Tram	7,223	85.5	3,569	73.4	6,800	41.5	9,600	24.0	10,800	18
Trollybus	293	3.5	326	6.6	2,400	14.5	6,200	15.5	12,600	21
Bus	550	6.5	300	6.1	6,100	37.3	21,000	54.0	33,000	55
Underground	377	4.5	668	13.9	1,100	6.7	2,600	6.5	3,600	6
Total	8,443	100	4,863	100	16,400	100	39,400	100	60,000	100

first place with the prospective use of the car hire system. In the post-war years the number of privately owned cars in the USSR has also grown rapidly.

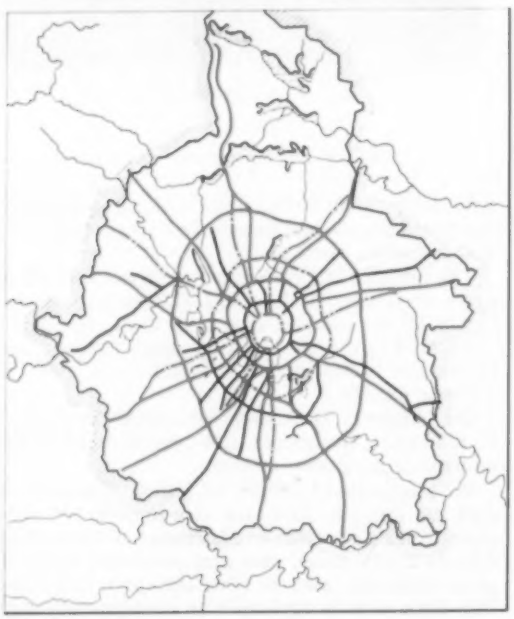
The following street classification and standards apply:

(1) All-purpose urban highways: width 45 to 70 metres.
(2) District main roads: width 35 to 50 metres.
(3) Residential streets: width 20 to 35 metres.
(4) Streets leading to warehouse and trading districts: width 25-40 metres.
(5) Motorways with limited access and uninterrupted speed, with a width of up to 100 metres.

Street Classification

Fig. 2 below shows the classification of the principal highways in Moscow.

Observation in many old towns in the Soviet Union showed that time spent by residents on travel grows continuously as the speed of traffic in the city's streets diminishes. Speed of trollybuses and buses in large towns is found to be limited to 15-17 km.; tramways, 10-12 km.; light traffic, 30-35 km. per hour. These speeds are about three or four times less than the design speed of the vehicles ordered for public transport.



Major Motorways
1st Class Highways
2nd Class Highways

Fig. 2. Scheme for classification of major roads in Moscow.

It should be noted that the 20th century, especially the second half, is characterized by the urge to increase speed, resulting in the need for continuous work on perfecting every aspect of the motive power of transport. Yet the tendancy to increase speed has not been utilized in towns, notwithstanding the practical beneficial result of higher traffic speeds. The reason for this is mainly the hold-ups at street intersections, and the release of the 'wave-like' traffic after its accumulation at crossings and lights. The building of pedestrian underground crossings (Fig. 4), though shortening the hold-ups, does not eliminate traffic lights which remain necessary to regulate traffic.

It is estimated that each Moscow inhabitant takes about 700 journeys a year, occupying 150 hours. By 1975 the number of journeys will grow to 900, with about 240 hours spent in journey time.

How can the continual slowing down of town traffic be explained while the number of journeys and time spent grows constantly? The trouble is that on its way organization of traffic and raising its speed meet with obstacles, above all, traditionalism in the planning of road networks. There is nothing stranger to contemporary town construction than the mechanical application of anything, even the very best traditions, without first studying the development and nature of changing conditions.

In fact the new conditions of contemporary traffic need a new arrangement of streets. Experience has shown that attempts to pour new contents into old streets of former design, lead to insurmountable repercussions which result in not only large economic losses but a worsening of living conditions.

Right-angled intersection of streets contradict the very purpose of mechanical transport, which calls for smooth curves (Fig. 3) but heretofore intersections have been designed in that way only; further, in contemporary conditions, to build boulevards along existing streets is also wrong, for this brings traffic closer to the walls of dwellings causing much discomfort and danger to residents, and, in particular, it increases the effect of noise and vibration on the inhabitants. Quietness should be obtained in the first place by routing heavy through traffic away from residential districts because not only residents but

also work is disturbed by noise. There is no doubt that the starting and stopping of an engine and the application of brakes increases noise significantly. This is the cause of the larger proportion of noise at town intersections. Therefore the need is to diminish the number of intersections. Persistent loss of time results not only from the actual location and design of streets but also from the lack of quiet in them. As the rapid growth of motoring spreads, this factor will play an increasingly important role.

In town construction there are occasions when the highest quality, highest accuracy and highest craftsmanship are the only possible answers, when there can be no transitional stages, but only 'first class' or 'reject'. Such a case is a contemporary city street which, through many centuries, must serve as a public right-of-way for millions of people. Hence from the moment a street is built it should be of highest quality in all its aspects.

Besides travel time, road safety must be taken into account in the construction of contemporary streets and must always remain a constant factor. This is, of course, the purpose of every construction project.

The town dweller does not know the meaning of road safety. This is natural, since in all parts of the world a man consciously strives for safety only as an antidote for danger.

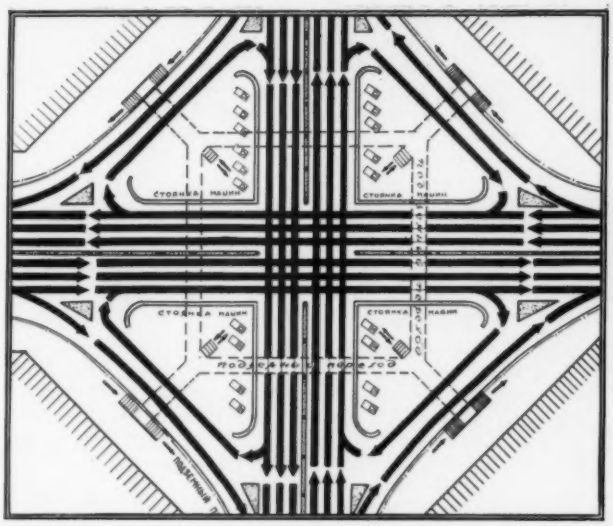
A well known physiologist, E. P. Pavlov established that under the influence of a certain pattern of life, a man's reflex system is conditioned to a certain stability, called 'dynamic stereotype'. So, for instance, a person finding himself for the first time in a large city, uses nervous energy to cross a street, especially at peak hours. An inhabitant of that city does this almost automatically and without exertion. His reflex system has become conditioned from habit and works almost independently of his conscience and willpower. This can be called 'stereotype movement'. Only a real and serious experience of danger makes a city dweller aware of the necessity for safety measures at street crossings. The largest proportion of accidents are caused by lack of pedestrian training in 'stereotype movement'. Towards this purpose, two measures are: the use of propaganda to promote road safety; and full use of development plans for the layout of streets.

In theory, a town's passenger service should reach out to the limits of a district, carrying people and transferring loads at different points with it.

By the use of observers and questionnaires, a percentage is established of the population and the distance covered by general and individual transport in USSR cities. In this way, exact information is acquired on the growth or reduction in different forms of transport and the tendancy of development in each separate form. A widely working method of this nature serves as a prognosis of the movement of traffic, and indicates the structural particularities of each town.

The investigation of such questions is known as 'mobility of population' and the use of this evidence is decisive for solving transport problems of town planning. The approximate mobility of population can be divided in the following way:

In defining date on transport mobility it is important to take into consideration not only the residential population but also the estimated journeys from other towns and suburbs into the town. This is



Barriers —— · ——
Traffic lanes ⟶

Fig. 3. Scheme for the intersection of two major roads. Each right angle of the intersection provides parking space and pedestrian subways shown by broken lines.

TABLE II
Number of journeys per year per inhabitant

Category of Town	*Number of Inhabitants*	*Maximum number of journeys*
Agricultural villages (State farms, large collective farms)	up to 1,500	40
Towns—mainly farming	from 1,500-1,700	100
Industrial settlements	from 7,000-15,000	125
Small Towns	from 15,000-100,000	210
Medium sized Towns	more than 100,000	350
Large Towns	from 200,000-750,000	550
Larger Towns	more than 750,000	650
Cities out of category	more than 250,000	900

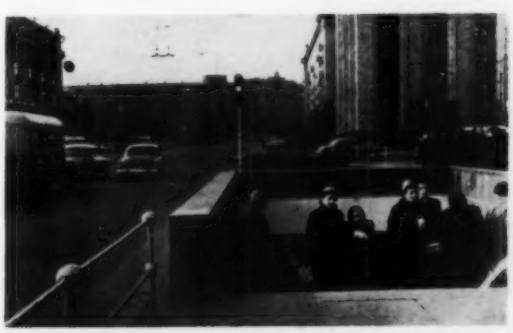


Fig. 4. Entrance to a pedestrian subway in Moscow.

especially important in the case of health resorts, of which at present there are 300 in the USSR.

In making future predictions it must be taken into account that the plan of mixing residential with industrial buildings will improve the existing situation by bringing living quarters closer to place of work. In new residential districts the distance between main streets leading to places of work, is about 600 metres. This greatly reduces walking distances to a stopping point.

The ease of approach to towns depends on the arrangement of road junctions in relation to the town plan, and to effect this, modern highways are being built for heavy traffic flows. To ask about present day arrangement of road junctions in a medium-sized town has as little sense as asking in the 20th century about a railway project to remote parts.

In medium sized towns situated along inter-town highways the density of transit traffic is very large, and in large cities such as Kharkov where highways meet, uniting Moscow–Kharkov, Kharkov–Simferopol, Kiev-Kharkov and Kharkov-Rostov, the density of transit traffic, especially in the summer months, reaches 30 per cent.

A well regulated flow of traffic is obtained to a considerable degree by the building of circular or semi-circular roundabouts along the highways. In the general plan for Moscow, Minsk, Kharkov and other towns, the project is to build outer, so called 'ring roads' for the flow of through traffic which will speed transport connection between motorways.

Turning now to problems subjected to scientific research in the transport and traffic fields of town planning, it is necessary to distinguish the following basic problems in turn:

(*a*) Assessment of the prospective size and composition of traffic on the basis of analysis of the present trips made by a town's population.

(*b*) Study of and planning for road safety with the use of modern equipment which is accepted as a complex problem by Town Construction.

(*c*) The study of the problem, created by the new aspects of road communication in towns, to guarantee a realizable design speed in advance, as well as absolute traffic safety.

Besides these general problems of scientific research, some serious problems remain, such as:

(*a*) Principles involved in planning a transport system by the decentralization of large towns and the establishment of satelite-towns.

(*b*) Principles involved in solving the problem of transit traffic.

Essential work by scientists on questions of contemporary traffic, shows conformity with the law of change, in that the composition and power of traffic is connected with the process of development of towns. In particular, the question arises, of the correct period of time for calculating a traffic development project in town planning. In the author's opinion we should take a rational 50-year period on which to base calculations for the projection of a transport network with a system of road communication and the forming of a hypothesis on town traffic.

Every science has its own method of investigation, and for the investigation into possible solutions of traffic problems, the very best method must be found. Contemporary transport technique provides a wide choice of remedies for their solution. However, the need is not for prescriptions, but a scientific method built on authentic initial data.

In particular, analytical method must be given full scope to 'sound out' the decisions on traffic problems. In the end the solution reached must be one based on the plan drawn up for the town, following its characteristic distance and direction for a final answer.

In conclusion, it should be said, that town traffic, transport, and pedestrians must all be organic elements in the general plan for the projected scheme for a town. In the USSR, this new scientific branch of town planning attracts a great deal of attention from practical and scientific workers in town construction.

Driver Behaviour at Traffic Lights (*concluded from page* 478).

Then the speed requiring the larger A is higher than the optimum for the intersection (and equals $V + \delta V$). This result is also obtained, by the use of binomial expansion, for any value of $\delta V < V$.

Example of the method of finding the amber period

It is assumed that the road in question intersects with another which is 90 ft. wide at the junction, and that traffic observations have shown that the mean vehicle speed is 40 mile/h. with standard deviation of $\pm$ 8 mile/h., and that the design should include 95 per cent of the speed range.

Then, since the mean speed plus twice the standard deviation includes about 95 per cent of the vehicles, it is first necessary to know whether 24 or 56 mile/h. will require the longest amber period. The higher speed will require the longer amber period if the inequality (12) holds good. (As before, V mile/h. is the mean speed, I ft. is the effective width (2/3 actual width) of the intersection and K is the constant the value of which depends upon the stopping threshold.) For the 95 per cent threshold $K = 0.581$. Since $0.581 \times 40^{1.6} = 213$ (see Table I in text)

$$> \frac{60}{0.6} = 100,$$

the upper limit of the speed range, i.e. 56 mile/h., will require the longer amber period.

Thus $A = \frac{0.682}{56}(60 + 0.581 + 56^{1.6})$ sec. (using Equation (7)). = 5.2 sec.

REFERENCES

[1]WOODWORTH, R. S. Experimental Psychology, New York, 1938, Henry Holt & Co. Inc. p. 402.

[2]Road Research Laboratory. Road Research 1960, London, 1961. H.M. Stationery Office.

[3]OLSEN, P. L. and ROTHERY, R. W. Driver's response to the amber phase of traffic signals. General Motors Corporation Research Laboratories, Warren, Michigan. Unpublished Report.

[4]GAZIS, D., HERMAN, R. and MARADUDIN, A. The problem of the amber signal light in traffic flow. Operations Research, 1960, 8 (1), 112-132.

ACKNOWLEDGMENT

The work described in this paper was carried out as part of the programme of the Road Research Board of the Department of Scientific and Industrial Research. The paper is published by permission of the Director of Road Research.

SIGNIFICANCE of HAMMERSMITH FLYOVER

Richard Edmonds

In the context of the L.C.C. roads policy, the Chairman of the Roads Committee, London County Council, describes London's first cantilever structure, which was opened to traffic on November 16.

ONE eminent critic of the roads policy of the London County Council—and I am delighted to think that he at last accepts that we have a policy—has said in recent days that the Council is being dragged unwillingly through the mid-decades of the twentieth century into the motorway age. How wrong that critic is in assessing the nature of that policy. Perhaps the construction and opening of the Hammersmith Flyover is in part the answer to him, epitomizing as it does much for which we are striving for London, including worthy links with the motorways that are coming to our door. In the context of the whole Hammersmith highway improvement, the flyover deals with both local and through traffic, ensuring above all a smooth link with the international airport which lies on London's western flank and with the important routes leading to and from the West Country and South Wales.

The Hammersmith flyover is a structure of great significance being economical in the use of land, a factor so often forgotten by road developers both on the continent of Europe and in America. Not only do four lanes of traffic 'fly' through the heart of Hammersmith at the upper level, but traffic is tucked neatly beneath the cantilever wings of the flyover both to the east and the west of Hammersmith Broadway. But for this economy acquisition of much more property would have been necessary at considerable cost in terms of finance and land.

Finally, and this point to my mind ranks equally with the two already made, the flyover is a structure of outstanding beauty and attraction, indeed something of a miracle in modern concrete. I think it will be remembered as one of the road pioneering landmarks of the twentieth century, just as the Forth Bridge and the Menai Bridge have their places in railway history of the nineteenth century. The Royal Commission on Local Government in Greater London, attempted to pillory the L.C.C., and all concerned, for the alleged delay in agreeing on the flyover, but apart from the fact that funds for London roads have been scarce until recently, it would have been quite wrong to attempt the flyover until such time as a structure of the kind now built had been devised, one of such ingenuity indeed that it could truly safeguard the amenities of central Hammersmith and its magnificent riverfront gardens. Some of the earlier plans for a flyover at Hammersmith actually envisaged up to 90 columns to sustain the roadway. One can well imagine the sort of slum conditions such a flyover would have created, a repetition of the worst follies and atrocities of the thrusting railway age in Britain, which only very occasionally paid tribute to amenity.

At Hammersmith there is a merging of three vital elements: traffic need, economical land use, and physical attraction, and it is with pardonable pride that the L.C.C. and all who have worked with it on the flyover scheme, advance its claim to importance in the history of modern roadmaking. I hope in the years ahead there will be many achievements along the same lines inside and outside the County of

London, and that the names of Rawlinson and Stott will be honoured in this vast field of enterprise in the way they deserve to be.

While I have taken the opportunity to present the Hammersmith Flyover within the general framework of road politics, road engineering and architecture, I should like at the same time to give readers a short review of the traffic history that lies behind this scheme which is, of course, part of a network of schemes forming a policy for the western exits of London, a network extending from Hyde Park—Marble Arch respectively through Knightsbridge and Notting Hill.

The story goes back to 1936 when the Cromwell Road extension was approved. It was actually in course of construction when war was declared, and was planned to by-pass Hammersmith Broadway. In doing so, however, it involved a signal controlled left-right stagger where it crossed Fulham Palace Road, and a skew roundabout at Hammersmith Bridge Road. When considering post-war road planning, it was realized that such an arrangement would not prove satisfactory. It will be appreciated, for instance, that it is not sufficient only to consider traffic from Central London to London Airport and South Wales, but rather that the complex traffic situation at this point should be considered as a whole. If maximum use were to be made of the new Cromwell Road an efficient interchange system would be required at this focal point. In this connection it should be realized that seven traffic roads meet here, making in all 42 traffic streams, only two of which—the largest—directly traverse the intersection between east and west.

On the basis of pre-war traffic data, a traffic engineering study was made, and a scheme designed which provided a viaduct for through east-west traffic, and a ground level one-way traffic scheme for distributing the remaining 40 traffic streams. This was designed to accommodate at least twice the pre-war traffic volumes in an east-west direction, and 50 per cent increase in the other directions. For this scheme the Council obtained Powers from Parliament in 1948, in spite of the fact that Government policy at the time did not provide for capital expenditure on road improvements. When in 1954 grant funds became available, the portion of the new Great West Road west of Hammersmith Broadway was put in hand first, as the land required was already available.

The next step was the improvement of the Broadway intersection itself, but grant funds were not then available for both the ground level section of the improvement and the flyover, and the problem was to decide which should have precedence. Bearing in mind that the east-west through traffic was only expected to amount to some 25 per cent of the total volume at the intersection, and the considerable local opposition to a viaduct, the Council decided in favour of constructing the ground level section first. This would in any case be necessary before the viaduct was built and in the meantime it would offer greatly improved facilities for all traffic. This policy has been justified by events, for the intersection is now carrying double the pre-war volume, with considerable savings in time. Following an origin and destination pedestrian survey a system of pedestrian subways was designed. But, because demolition of important buildings would have been involved,

ramped approaches have not been provided in all cases, and no subway is yet possible under Hammersmith Road.

It is interesting to note that the predictions of the vehicular traffic study made in the forties, although they were based on limited traffic data, have been largely realized. King Street has been relieved of about half its traffic as predicted. There has been rather more traffic on the Great West Road than was expected, however, especially in the morning and evening peak periods, owing no doubt to diverted and new traffic as well as to the general post-war increase in commuter traffic. Some difficulties were experienced at first in the operation of the one-way system, not as was expected in the rather narrow Hammersmith Road arm, but in the south-west corner. This particular difficulty was caused by the discovery of a disused burial ground under the Old Church School, which at first made it impossible to proceed with the construction of the entrance to the pedestrian subway already built under the new road. It was therefore necessary for vehicles to stop to enable pedestrians to cross on the surface, and inevitably this caused some blocking back. With the eventual construction of the subway entrances, however, and a solution having been found, after trial on the ground, to the difficult problem of obtaining the best weaving layout within the Broadway itself, the ground level system is now carrying 7,800 vehicles/hour at the morning peak period, or 8,650 if the small triangular roundabout is included[1].

In 1956 the Ministry of Transport authorized the construction of the flyover, for which property acquisition had already been started and provision made in the layout of the ground level scheme.

Carriageway Dimensions

The flyover, which carries two lanes of traffic in each direction, rises in the west between the dual carriageways of the Hammersmith-Chiswick section of the Great West Road, and from there runs over Hammersmith Bridge Road between St. Paul's Church and the Gaumont Cinema, then over Queen Caroline Street and Fulham Palace Road, and thence into Great Church Lane near Colet Gardens. Part of the west-bound arm of the roundabout is oversailed by the cantilever construction of the roadway. The two carriageways are each 24 ft. wide and the overall width is 61 ft. The flyover gives 16 ft. 6 in. clearance for traffic beneath, and superelevation is allowed for at the curving eastern approach. Balustrades needed as protection for people using the crowded thoroughfares below are of modern design in steel. Electric heating cables are embedded in the surface throughout for use when necessary to prevent icing.

A more recent traffic survey shows that the flyover is expected to be used by 28 per cent of the total traffic passing through the intersection, so relieving traffic conditions at the ground level. This means at present-day traffic levels, a peak of 1,550 veh./hour on the viaduct in one direction. A much greater volume of through traffic could be carried on the viaduct which would allow for the new traffic attracted to the through route as well as natural increase. The motor traffic in 12 hours through Hammersmith Broadway was 29,000 in 1939. It was much less immediately after the war, but had risen to 30,000 by 1954 and 46,000 in 1958. The traffic flow reached 62,000 in 1960 after the ground level scheme had been substantially completed.

The flyover is a prestressed concrete structure arranged in 16 spans, its 2,043 ft. of suspended structure is flanked by approach ramps which increase the overall length of 2,831 ft. It is 61 ft. wide, made up of two 24 ft. carriageways separated by a median strip. The main structural element is a continuous hollow spine beam 26 ft. wide and varying in depth from 6 ft. 6 in. at midspan to 9 ft. at the supports. It is formed of beam segments 8 ft. 6 in. in length which alternate with 12 in. thick transverse cantilever units. The units are prestressed together by longitudinal cables of $1\frac{1}{8}$ in. diameter which pass through the hollow spine beam in four clusters.

The Cantilever Structure

The reinforced concrete cantilever units serve a dual purpose; they act as diaphrams for the spine beam, and their outer arms support the precast reinforced concrete slabs 8 in. thick, which form the outlying sections of the carriageways. The cantilever units, shaped like inverted coat-hangers, are 12 in. thick and 59 ft. long and have a maximum weight of 15 tons. They vary in depth from midspan to the supports, matching the neighbouring beam segments. The arms which protrude on either side are tapered in depth, and these repeat along the entire superstructure. Each cantilever arm is heavily reinforced. Each column which is tapered and hollow is connected to the spine by vertical prestressing bars. Each is built on top of two roller bearings placed on the concrete foundation. This arrangement allows the flyover with its columns to move longitudinally under temperature changes like a long narrow table on a series of legs each with double castors.

The beam segments, which are placed over the column, are prestressed to them by means of 24 Lee-McCall high tensile bars of $1\frac{1}{4}$ in. diameter. These bars pass right down the walls of the columns inside ducts with their lower anchorages cast into the column foot. The bars are stressed from the top, and besides stitching the beam segment to the column, they also provide sufficient stress for the columns to resist both longitudinal and lateral bending. These particular beam segments are further stressed by six similar bars passing transversely in ducts through the top flange. The longitudinal prestressing of the spine beam is provided by $1\frac{1}{8}$ in. diameter stranded cables using the Gifford-Udall system.

To prevent icing on the carriageways, the road surface of the entire flyover can be electrically heated by means of cables embedded in the surfacing. Automatic controls ensure that the system is brought into operation only when conditions of both temperature and humidity are such that ice can form.

Designing the flyover, the consulting engineers G. Maunsell and Partners, worked in close association with the Council's Chief Engineer, Joseph Rawlinson, C.B.E., M.I.C.E., and the Council's Architect, Hubert Bennett, F.R.I.B.A. The contractors were Marples Ridgway and Partners Ltd.

[1] ASPROTH, B. K. Weaving Capacity of Hammersmith Broadway Roundabout. Traffic Engineering & Control, October, 1961.

DEVELOPMENTS

Top: *The new bridge over the River Tamar between Devonshire and Cornwall has been opened. This bridge, for which no government grant was made, has a total suspended length of* 1,848 *ft. and was built by the Cleveland Bridge & Engineering Co. Ltd. using cables by British Ropes Ltd.* **Centre and Bottom:** *The new Carbridge in Birmingham, a prefabricated, portable flyover erected recently in only* 30 *hours. Designed by Major Strologo of the R.A.C., this type of construction is serviceable for at least* 25 *years and can be built in single or multi-lane form in a minimum time and very economically. The contractors are Lysaght's Bristol Works Ltd.*

ILLUSTRATED

Top: *A recently constructed viaduct on the Autostrada of the North near Lisbon, Portugal. The graceful concrete work is worth noting. (Photo: International Road Federation).*
Centre and Bottom: *The Pompeii-Salerno Autostrada in Southern Italy. This road, which is* 18 *miles long and* 63 *ft. wide, has been specially designed to blend with the very fine scenery. An unusual feature of the construction is that in many places, two of which are shown in these photographs, the carriageways are built on different levels. Reinforced concrete has been used for all structures including the Caiafa Bridge below. Numerous parking areas have been laid out for tourists. (Photos: Etude Routière).*

PROFILE

JOHN L. BECKETT

HALF the projects with which I have been associated during my life, and those upon which I am working today, I shall never see fully completed.' Thus said John Beckett, City Engineer, Surveyor and Planning Officer to the City of Leicester for 20 years. In these words can be found the key to much of the thinking of this 62 year old, Liverpool born technologist. For he thinks in 10 and even 50-year periods and he plans for the future as much as he does for the present. He is recognized as one of the most forward thinking planning officers in the country and a pioneer in the development of ring roads.

He trained under, and worked with, the late J. A. Brodie, the man largely responsible for the magnificent engineering feat of the Mersey Tunnel, who advised on the planning of New Delhi and who was acknowledged, even in his lifetime, to be one of the greatest road engineers of the century. 'Yes, a very great engineer and planner indeed', said Leicester's City Engineer. 'He was far in advance of his day, and so was Professor Patrick Abercrombie. I took my first Town Planning examination in 1923, after studying Civic Design under him at Liverpool University'.

In 1927 he worked at Runcorn, leaving in 1930 to become Borough Surveyor to Tynemouth, Northumberland, and met and married a Newcastle girl. After some six years on the north east coast, he went to Burnley and in 1941 he accepted the threefold position of Chief Engineer, Surveyor and Planning Officer for Leicester. For 20 years therefore, he has had as his responsibility the growth and welfare of a city of over 300,000 people, and he has, intimately and from day to day, been concerned with the long-term planning of its roads and its civic facilities.

He is a Member of the Institution of Civil Engineers, a past President of the Institution of Mechanical Engineers, and was last year chosen as the first President of the newly formed International Federation of Municipal Engineers. He is Vice-President of the Town Planning Institute and a Member of the Royal Society of Health. But despite these imposing titles and heavy responsibilities, there is nothing of the technical pundit about him. He does not seek to 'blind with science' but to enlighten, an attitude, perhaps, born of many years of explaining to, even cajoling, local councils, committees, boards and ministries, in order to put his plans into action.

'I think', said John Beckett, 'that the pattern of the future will eventually be one-way traffic circulation. We are, in Leicester, already planning for 1970 by laying down now inner ring roads with radial roads linked to the main highways. Lying as it does, almost at the centre of England, Leicester is fortunate. Also it has never really suffered unemployment, severe bombing or uncontrolled urban sprawl. We have the latter to some degree, but in the main we are managing to control excess by planning. As long ago as 1944 we held a public exhibition of reconstruction proposals for Leicester, and invited suggestions and criticisms. An example perhaps, of Public Relations in Local Government. Even then we began to plan a town geared to the "wheel age". In 1954 we allocated nine sites in the centre for car parking, and in a second survey in 1958 we planned seven of these nine sites as future multi-storied car parks. We must, in our building within the city limits, go either up or down. It is usually cheaper to go up.'

Together with Beckett's acute awareness of the need to plan in direct ratio to the increase of motor vehicles coming on to the roads each year, and the necessity to provide facilities within the town itself, his service to his adopted city embraces all manner of projects. In 1944, riverside development was planned, unattractive low-lying ground was filled in and today there are fine public gardens skirting the river's edge. An open air theatre is envisaged and a sports stadium capable of holding 70,000 people is nearing completion.

He does not believe in the policy of keeping cars outside the centres of cities. 'Ring-roads, one-way traffic, parking meters and multi-storied parking, if all these methods are used and planned for in sufficient numbers and on a national scale, I believe we can keep our traffic problems under control', he said. Staggered hours he considers as a helpful device, but not practicable. 'It is too academic a proposal, demanding as it does too great a change in social habits. Parking meters have helped to solve much of the traffic congestion in large urban areas, but road planning is the real answer.'

Beckett travels a great deal both in Great Britain and abroad, studying different methods of road planning and engineering. As an ex-pilot himself he believes in the usefulness of the aeroplane. 'Helicopters could be very useful as inter-city communication in this country. Once the problem of noise has been overcome, and I have no doubt that it will be, large urban areas will be planned to include launching and landing sites for helicopters. I can well imagine bubble-cars with wings carrying passengers and goods between our cities and towns.'

To John L. Beckett, City Engineer, Surveyor and Planning Officer, it is quite clear, the building of the Mersey Tunnel during the twenties and the planning and construction of ring roads for the seventies, is all in a day's work. With his vision of brightly coloured bubble-cars carrying commuters in the sky over Leicester, it is also clear that it is work that he thoroughly enjoys.

NEW PUBLICATIONS

Factors Affecting the Amount of Travel. D.S.I.R., Road Research Technical Paper No. 51. (H.M.S.O.). 2s. (2s. 4d. post free), U.S.A. 34 cents.

The factors affecting the amount of travel between areas are undoubtedly complex but attempts have been made particularly over the last 10 years to express them in the form of a simple relationship. The advantages to be gained from this are of course very real. If successful it would mean that methods would be available for estimating the changes in travel patterns brought about by proposed improvements of transport facilities, growths in population or changes in land use. Normally the theories which have been developed are of the gravity model type, so called because of the similarity to Newton's law of gravitational attraction. As applied to traffic, theories of this type state that the attraction of two areas (i and j) expressed in the number of journeys per unit time (t_{ij}) is directly proportional to the product of the sizes of the areas e.g. populations (P_i and P_j) and inversely proportional to the n'th power of the time or distance between the areas or

$$t_{ij} = \frac{K\ P_i\ P_j}{d_{ij}^{n}}$$

where K is a constant usually independent of i and j. The author demonstrates quite clearly two basic weaknesses in this simple formula. These are concerned with the use of the product of the populations (or sizes) and the inverse n'th power of the distance (or travel costs). Considered logically the use of the product of the populations in this expression leads to the false result that the amount of travel per person is approximately proportional to the average population density. In extreme cases this is obviously false. In fact, using information given in a report of an enquiry into household expenditure in 1953-54 by the Ministry of Labour, it is shown that persons living in urban and in rural areas travel about the same average distances per week. Also assuming a reasonable valuation of time the average total expenditure per person on transport is approximately the same in both types of area.

Analysing the use of the inverse n'th power of distance for certain theoretical cases gives results which are not consistent for traffic within towns and between towns or for very short and very long distances. Therefore if a basic expression is sought which is to be generally applied, an alternative function of distance is required. The author puts forward as an alternative the function

$$f(d) = \frac{e^{-\lambda d}}{d^{n}}$$

where λ is a non-negative constant and n is a constant certainly less than 3 and probably less than 2. He shows that this expression satisfies the theoretical cases. Relevant data in the report on usual residence and workplace from the 1951 census of population is then analysed using four statistical methods (varying in complexity and accuracy) to give values of λ and n for various areas. Among the areas considered are the metropolitan boroughs, the city of Westminster and the Manchester county borough. From the results obtained it is concluded that although λ and n vary considerably for practical cases it is reasonable to assume an arbitrary value of n (say 1 for ease of computation) and choose a value of λ to fit the data. If this is done the distance function simplifies to

$$f(d) = \frac{e^{-\lambda d}}{d}$$

Having shown that the usual simple gravity model law is inadequate to cover all cases the author derives a new theoretical model:

$$t_{ij} = \frac{m\ P_i\ P_j\ e^{-\gamma d_{ij}}}{d_{ij}} \left[\frac{1}{\sum_{k=1}^{N} P_k\ e^{-\lambda d_{ik}}} + \frac{1}{\sum_{k=1}^{N} P_k\ e^{-\lambda d_{jk}}} \right]$$

where m = mileage travelled per person per day.

In deriving this expression it is assumed that there are N places each of which is small enough for internal traffic to be negligible. It is also assumed that transport costs per person mile are constant, that all journeys are home-based and that m has the same value in all places. The expression includes the distance function previously put forward and whilst the product of the population is still present it is modified by two factors which in the words of the author are exponentially weighted average population densities in the areas surrounding places i and j. Intuitively this type of weighting seems to be correct since the areas surrounding two places under consideration must influence to some extent the travel between them. This model appears to be a step forward but it has still to be put to the test particularly for very small and very large distances. While most of the paper deals with transport as a whole it is felt that the results obtained can be applied to road traffic on its own.

Taken in its entirety this is certainly not a paper for the interested layman, many trained engineers will find difficulty in following it at the first reading, and in fact certain of the finer points will probably evade all but the trained statistician. Also the reader will probably tend to lose the main thread of the analysis in the section where the author extracts and applies the relevant data from the two government reports. To say all this does not cast any reflection on the way in which the author has written the paper but is rather a comment on the complexities of the subject. For any who wish to extend their thinking in this aspect of traffic engineering it is well worth their time to study the report, which is a valuable addition to the long list of useful publications issued by the Road Research Laboratory. T.C.

Town and Traffic in the Motor Age, by P. H. Bendtsen. Danish Technical Press. 38 D Kr.

In his paper to the recent World Traffic Engineering Conference, J. D. Carroll said that 'the state of knowledge about the metropolitan body is probably somewhere near the medical knowledge of the human body at the end of the 19th century'. Professor Bendtsen's book is an admirable digest of the present state of knowledge of cities as traffic organisms, and of the effect of various cures for traffic ills. He has drawn on the fruits of research in many countries, including the work of the Road Research Laboratory, although most of the data he gives are for American cities simply because far more research of this kind has been done in the United States.

One point in the third chapter needs correction. The Author refers to B. Campbell's suggestion that modern arterial roads with signal-controlled intersections might be a better investment than motorways in certain parts of a metropolitan region. Campbell did not say that a single road of this type would have the same capacity as a motorway; he said that *two* roads of this type would have the same capacity as a motorway and would cost about the same. He suggested they might be preferable to motorways in suburban areas, between three and 10 miles from the city centre; he fully accepted the need for motorways in the inner area, within three miles of the centre, where volumes are highest.

Bendtsen reaches rather pessimistic conclusions regarding the improvement in traffic speed to be expected as a result of building either underground railways or motorways in big cities. The Yonge Street subway in Toronto led to some immediate improvement in speeds on that street, but within three years speeds were back at their old level due to an increase in car traffic. He calculates the effect on costs of travel of building (*a*) an underground railway and (*b*) a motorway on the line of Fredensgade, one of Copenhagen's main radial streets. He reckons that the motorway, though costing only £1,600,000 per mile, would not produce a 'balance of savings' to cover interest on the capital invested. As for the five radial motorways planned for Copenhagen, they would merely suffice 'to stave off a traffic breakdown until the number of motor cars has risen to 250 per 1,000 inhabitants.'

In the chapter on 'Parking in the Central Area', he reaches the conclusion that 'as the number of motor cars increases . . . all the major European provincial cities are likely to be short of

(*Concluded on page* 502).

PARKING PROBLEM solved in DETROIT

J. D. McGillis

Fig. 1. Cobo Hall roof parking deck. Note direct access from freeway to spiral ramp of which the centre lane is reversible.

IN 1948, the automobile manufacturers of Detroit resumed civilian production and were doing a fine job of meeting the demand for new cars. People were forsaking public transportation by the thousands and downtown streets became heavily congested. Little or no attempt to increase off-street parking was being made. Operators of facilities were apparently content to continue the status quo, because the greater the shortage of space the higher was the income. Incalculable time was lost by individual motorists seeking places to park and there was an increase in accident potential due to excessive and distracted driving in the search for somewhere to stop. These factors constituted a warrant for municipal action.

By 1961, the annual number of riders on public transportation had decreased from 420 million to 135 million; passenger automobile registrations had increased from 650,000 to 955,000 and now there are over 150,000 vehicles entering the central business district each working day. Nevertheless, traffic congestion in the core of the central business district has practically disappeared and there has been a marked decrease in accidents. In the face of the figures, this is an achievement.

Provision of Parking Space

There are a number of reasons why it was possible, but perhaps two of the most important are the opening of the freeways and the municipal parking programme. The north-south freeway was completed, from the central business district into the residential area, for a distance of over nine miles. Two-and-a-half miles north of the central business district it intersects a crosstown freeway extending well beyond the city limits in both directions. The Municipal Parking Authority has constructed and placed in operation six large off-street parking garages, in addition to three surface parking lots. The garages have been related to the freeway and to the principal arterial streets in such a manner that the city's traffic engineer estimates over two million automobiles carry passengers to the central business district each year without getting into local, central business district traffic.

In 1948, the City of Detroit determined that it would fix responsibility for solving the parking problem in a new city department. An ordinance was passed establishing the Municipal Parking Authority and making it responsible to the Mayor and the Common Council. Since then over 7,300 permanent parking spaces have been put in operation in the central business district, some of them being constructed by the Municipal Parking Authority. Private capital, inspired by the municipal programme, built another 2,000 spaces.

One of the most unique structures is a parking area on the roof of Cobo Hall, Detroit's new convention and exhibition building. This roof parking deck, illustrated in Fig. 1, with an area exceeding 350,000 sq. ft., was built at a cost of $2,000,000. It is reached by a bridge leading directly from the principal downtown freeway, with a spectacular three-lane circular ramp for use by motorists in driving from the street level to the parking deck. 1,217 separate parking stalls, with a dimension of 18 ft. by 8 ft. 6 in., are served by 22 ft. driving aisles. The roof parking deck averages over 1,500 cars per day and has accommodated as many as 4,800 cars in one 24-hour period. All cars are parked by the driver. In no case is one car blocked by another.

All municipal facilities are designed so that automobiles may be self-parked. After the motorist has parked and locked his car he takes his keys with him, secure in the knowledge that no one will be moving his car around when he is gone. The Authority learned early that this is a most important feature in the mind of the motorist. Thus, in designing and constructing the Cobo Hall Roof Deck, the Cobo Hall Parking Garage, the Second and Howard Garage, the Arena Garage, the Ford Auditorium Garage and the Grand Circus Park Underground Garage (Figs. 2 and 3) this self-park factor was incorporated and it has come to be the accepted method of providing parking in a majority of the new garages constructed in the United States.

Underground Garages

Three of the garages are completely underground. Detroit is fortunate in having, or being able to construct, park areas where it is possible to place a double burden on the land by parking automobiles under the surface while maintaining the openness provided by parks and plazas. The fact that the cost of the land did not need to be absorbed as a capital cost justified the additional expense of underground construction. Land and construction costs of above ground structures would have amounted to more than the construction cost of the underground facilities.

The Municipal Parking Authority has not confined all of its efforts to the central business district. Where parking was needed in major outlying business centres, off-street parking was constructed. Parking lots with capacities ranging from 26 cars to 354 cars were built at 13 different locations, and now over 2,000 parking stalls are in operation in these places.

In developing its facilities, the City of Detroit has called upon the skills of its several agencies. So that proper emphasis may be placed on traffic considerations and land use, the Municipal Parking Authority works almost as a team with the City Plan Commission and the Department of Streets and Traffic in choosing locations, making determinations as to size, positioning of entrances and exits, etc.

In planning relief of traffic congestion in the central business district, the needs of the motorist were considered in three different categories. First, the errand parker, that is the man who needs to make one short stop for a bank deposit, to pick up a package, to make a small purchase, etc. For him the most convenient space is at the kerb if it can be provided there. In many areas of the central business district of Detroit it can and is being provided. In the second category is the business or shopping parker, whose car will be stored for an average of three to four hours. He needs space close to his destination which is most often precisely in the heart of the congested areas. If parking is not provided at this location he will be inclined to cruise around seeking space and will add to traffic congestion. The third, the all-day parker, is the person who finds it convenient to drive his car to work each day. Because his parking fee is a daily expense he is willing to walk a little farther and expects to pay a lower rate than that of the business or shopping parker. There was a shortage of all types of space, with most of the available parking in surface parking lots. These lots generally were irregular in size and shape, inadequate in capacity and without stability of rate schedule. They were haphazardly distributed without regard to parking demand, convenience to the motorist, traffic flow problems, land use or land values. Their temporary and transitory tenure encouraged the operators to try to obtain the maximum return with minimum investment and expense.

Choice of Location

The City of Detroit attempts to provide off-street parking for the third group, the all-day parker, near the freeways but for the second group in large garages located on arterial streets leading to and from the freeways. Experience has shown that these large structures, designed for self-parking, act as a sort of a vacuum to bring cars in from the street. In the Grand Circus Park Underground Garage the number of cars which may be parked at one time would occupy the equivalent of five miles of street kerb space. When the driver can quickly drop out of street traffic into an entrance separated from pedestrian walks and go directly to his parking stall, he is removed from that street traffic which might mill around on local streets looking for a place to park. These large garages can accept and discharge cars at a very high rate. This speed and convenience has resulted not only in lower accident claims but in a higher turnover of the use of the facilities themselves and a greater net revenue for the facility. The Cobo Hall Roof Deck, when filling in the morning, at times accepts cars through two toll booths at a rate of more than 1,000 per hour.

In its early investigations the Parking Authority determined that in congested areas off-street parking was merely an extension of the street system. It further determined that if the needs of the public were to be met, permanent off-street parking, properly located, adequate in size and design and operated at reasonable rates, must be provided. These determinations agree fully with the current policy statement of the American Municipal Association which reads in part: 'In congested areas properly designed, located and operated off-street parking facilities are traffic reservoirs and, as such, are indispensable parts of street systems. For the welfare, safety and convenience of its

Fig. 2. Grand Circus Park, the site of a 1,025-space garage. A car may be seen entering on far right. An exit shows left centre. Other entrances and exits are at the top of the picture.

citizens' each municipality should determine basic parking policies and should do such things as may be necessary to carry out these policies, which may include the planning, financing, construction, operation and regulation of off-street facilities as a legitimate, expected and necessary public service'.

Consideration of Drivers

The Municipal Parking Authority believes it is important to remember that the parking problem concerns people and not automobiles. It is the driver and the passenger whose convenience must be served. They will determine whether parking space is well located to serve their needs, whether the rates are reasonable, whether the service is good or poor and whether the time necessary to park and unpark the car is too long. A survey made by the Municipal Parking Authority showed that 95 per cent of the motorists interviewed preferred to lock their cars and a surprising 89 per cent indicated they would pay a reasonable additional amount for this privilege.

The automobile parking system of the City of Detroit is entirely self-supporting and does not involve general tax funds nor the faith and credit of the city. The Parking Authority determined that the best approach for the City of Detroit would be to combine its on-street and off-street facilities. Revenue from the facilities is used to repay funds borrowed for their construction. In this way the off-street parking is paid for by the users, the motorists, and at no time has it been necessary to use general tax funds. Such a system makes it possible to provide parking in some areas where it is needed but not economically practical, since each parking facility within the system need not be self-supporting. The good ones help carry the bad. This seems to be particularly important because many experts are convinced that there are no large profits to be made from off-street parking if it is properly provided in adequate quantity and at reasonable rates which the public can and will pay.

The automobile parking system has borrowed on its own credit $8,415,000 through the sale of revenue bonds, $7,965,000 of which are still outstanding. In its operations to date the automobile parking system has made interest and bond payments as they became due and has established an interest and redemption reserve in the amount of $470,000. In addition, a special emergency repair fund in the amount of $86,000 was created for use when and if needed. At the close of its fiscal year on June 30, 1961 the system had a surplus in excess of $2,500,000. which will be used to expand the parking system as needed.

Currently architects and engineers are busy designing three more underground garages which will have a combined capacity of over 1,600 cars. One of these will be located in the city's important Cultural Centre. The other two are in the central business district. Of the latter, one will serve both shopping and financial districts and the second one will serve the financial district and the Civic Centre. Three large new office buildings and a new proposed downtown hotel create the need for the new central business district parking construction. Detroit's municipal parking is designed to anticipate new demands and to be ready to meet them when they are created.

Conclusion

In developing the system described here, Detroit officials feel that they have filled the needs of the people, with the users of the facilities paying for them. These officials do not share the concern expressed in some quarters that the increased use of the automobile will cause the glutting of the central business district. They are confident that in combination with the freeway system, they can expand off-street facilities as much as necessary to accommodate all of the people in the metropolitan area who care to drive to the central business district. They believe that the automobile parking system which has been developed for Detroit is flexible enough to take care of future needs.

Fig. 3. Grand Circus Park underground garage during construction. The centre portion was put in place, then the banks of earth on the perimeter were excavated and construction completed.

Research into HIGHWAY TRAFFIC ACCIDENTS

by

H. J. H. Starks, *B.Sc., Ph.D.,* **F. Garwood,** *M.A., Ph.D.,*
G. O. Jeffcoate, *B.Sc., and* **R. J. Smeed,** *B.Sc., Ph.D.*

The Road Research Laboratory presented at the World Traffic Engineeering Conference a paper on Research into Highway Traffic Accidents conducted at the Road Research Laboratory, and in view of this valuable summary of the work undertaken there and of some of their findings, it is reprinted in full.

FOR the past 15 years, the Road Research Laboratory of Great Britain has carried out research with the object of finding practical methods of reducing the frequency and severity of accidents, and of facilitating traffic flow. The investigations have covered all parts of the subject except the medical, this being conducted by another Government financed organization, the Medical Research Council.

Some of the work on safety consists of studies of the accidents which occur on the roads, and some of the methods and results of these investigations are described in this paper. There are other road safety studies which do not use accident information as their immediate raw material, and this part of the work will not be described in this paper. Examples of these are the design of vehicles, crash helmets and safety harness in order to minimize injury, the factors in the tyre and the road surface which affect the liability of the vehicle to skid on wet roads, and devices to test vehicle brakes and lights, etc.

Information Sources

In order to learn more about factors contributing to accident frequency and severity, basic information on accidents and a great deal of background information is required. In Great Britain, the main source is a standard form completed by the police giving certain details of every personal-injury accident reported to them. Some police forces record some details of non-injury accidents and the records of these accidents are also usually made available to the Laboratory for research purposes. Several road accident insurance companies have made their records available to the Laboratory for analysis. These are especially useful for studying such matters as repeated accidents of particular drivers.

Detailed information about particular accidents is obtained from on-the-spot investigations of accidents made by the Laboratory staff with the co-operation of the police, on roads within about an eight-mile radius of the Laboratory. A team goes to the scene of the accident as soon as a report has been received from the police that an accident has occurred. Photographs are taken of the scenes of the accidents, sometimes with a special camera, mounted on a pneumatically-operated telescope mast, which takes a picture from a height of about 45 ft. Damage to vehicles or other objects concerned is also photographed. Particularly noted are the road features; evidence of the manoeuvres of the vehicles from road or tyre markings and the damage sustained are closely examined. Sometimes tests are made on the vehicle or its equipment, and sometimes the skidding characteristics of the road surface are measured. With the co-operation of the Medical Research Council and the local hospitals, particulars of the injury, if any, are obtained at the scene or subsequently if the injured people receive medical treatment, and attempts are made to find out how the injuries are caused.

Much can be learnt from accident studies without necessarily deciding on the cause of each accident, or even of contributory factors. Although such cause information is often useful, statistics based on it can sometimes be misleading, and it is important to bear in mind all the time that the objective of the research is to find practical measures, whether they employ the methods of engineering, enforcement or education, of reducing the frequency of accidents, particularly of the more severe ones. The more direct the evidence obtained that such measures are or will be effective in cutting down accident frequency, the more valuable our work will be. Directly related to the search for such evidence is, of course, the study of the comparative rates at which accidents occur in different conditions.

Only two of the main sources of background information will be mentioned here. The first is the data on traffic volumes using the roads of Great Britain. Traffic counters have been placed at 50 points on the roads of Great Britain—the points being chosen in such a way that the readings of the counters give estimates of changes in motor-vehicle-mileage that take place in Great Britain. In this way the vehicle-mileage, on any day, month or year since January 1, 1956 can be estimated.

Another important main source is the investigations carried out by the Laboratory on the characteristics of the

road system of Great Britain. 1,123 points on the road system were selected in a way calculated to give an estimate of the characteristics of the road system.

A knowledge of the conditions under which accident rates are high and the conditions under which they are low, is of value in guiding research and accident prevention policy. An attempt is therefore made here to give a general picture of the road accident situation from this point of view. The results of an international comparison of accident frequencies is first given, and they are followed by the results of investigations into the effects of road layout, road surface, type of vehicle, changes in vehicle design, and of traffic regulations.

International Comparisons

When comparison is made of numbers of fatalities, numbers of motor vehicles and populations in different countries, a fairly definite picture emerges. In general, if the number of fatalities per registered motor vehicle in any country is high the number of fatalities per unit of population is low. In addition, in all countries, there is a long term tendency for the number of road fatalities per vehicle registered to fall and the number of fatalities per unit of population to rise. This tendency is not very different in the different countries and, in fact, the number of road fatalities, D, corresponding to a number of vehicles, N, and a population, P, is approximately related to N and P by the formula $D = 0.0003\ (NP^2)^{1/3}$. By putting the formula in the alternative forms

$$\frac{D}{N} = 0.0003 \left(\frac{N}{P}\right)^{-2/3}$$

and

$$\frac{D}{P} = 0.0003 \left(\frac{N}{P}\right)^{1/3}$$

all of the above tendencies follow. It is remarkable that this formula, which was originally put forward in order to summarize data for 1938 for a number of countries, holds equally well for other years since that date. It has rarely been found to be in error by more than a factor of two. The result presumably means that road users take more care and the authorities take more action as the dangers on the roads increase and that the amounts by which they do so are not enormously different in different countries. The formula cannot be said to imply that the number of road deaths is predictable, and there is little doubt that, if sufficient precautions are taken, road accidents could be reduced to small proportions.

Other trends are also noticeable when comparing accidents in different countries. It is found that, as the numbers of motor vehicles increase, the number of fatalities and casualties to drivers and passengers of motor vehicles increases much faster than the number of pedestrian casualties. The ratio of one-vehicle accidents to total accidents also decreases, and the ratio of slight to total casualties increases when the number of vehicles in the country increases.

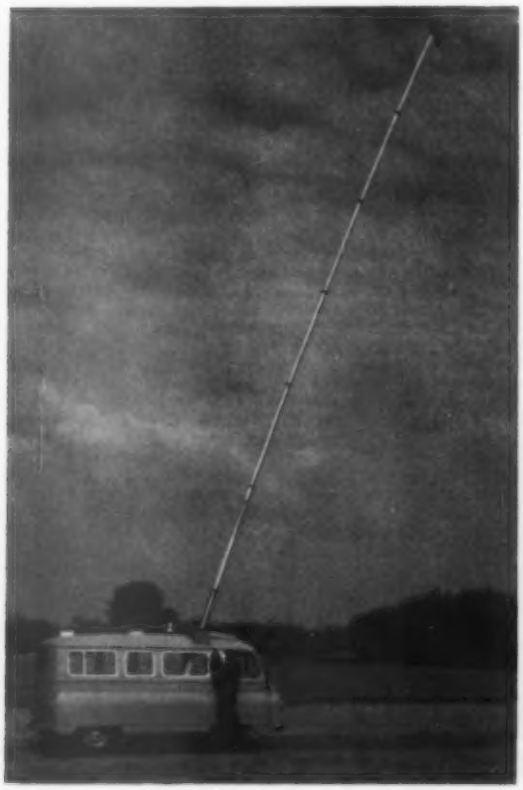
If possible it is desirable to base international comparisons on death, casualty or accident rates per vehicle-mile, since this makes a more accurate allowance for the varying usage of the roads in the different countries. This method also has the advantage of enabling a comparison to be made of an overall accident rate for a country with the accident rate on a particular road, or on roads of a particular type, or with the accident rates of particular classes of vehicle for which the vehicle mileage data are available. There are, of course, considerable difficulties about estimating the vehicle-miles travelled on all the roads of a country. In the case of Great Britain a variety of sources have been used and independent checks which have been made suggest that the result is reasonably accurate. Corresponding figures for the United States are given in the National Safety Council's publication 'Accident Facts', and the two sets of figures enable the following comparisons to be made:

No. of fatalities per 10^8 motor vehicle-miles* (1959)

	U.S.A.	*Great Britain*
Pedestrians ...	1.1	3.8
Pedal cyclists ...	0.07	1.1
Others... ...	4.3	4.9
All road users	5.4	9.7

**Based on 'Motor vehicle deaths' in U.S.A. but on all road accident deaths in Great Britain.*

The higher pedestrian fatality rate in Britain may be due to a greater proportion of mileage of vehicles being in built-up areas than is the case in



On left: Pneumatically operated mast carrying camera used by the Road Research Laboratory for taking plan views at sites of accidents investigated by their Accident Investigation Team.

Below:
Plan view of an accident site as revealed by the camera.

America. The higher pedal cycle figure is, of course, due to the much larger number on British roads. The British figure for the remaining group can be broken down as follows:

Motor cyclists and passengers	2.5
Drivers	1.1
Other passengers	1.3
Total 'others'	4.9

Thus over one half of the British fatality rate for this group comes from the motor cycle, a machine which is used very little in the States, and which —see below—is known to have a high personal-injury accident rate; the remainder, 2.4, from drivers and passengers of four- (or more) wheeled machines can be compared with the bulk of the corresponding American figure of 4.3.

Accident Rates on Different Roads

The risk of travelling on different types of road in Britain has been examined and Table 1 summarizes some of the data. In a shopping street the number of personal-injury accidents is usually about eight per million vehicle-miles travelled, and on a motorway it is 0.7. Consequently one is more than 10 times as likely to be involved in an accident when travelling a given length of a shopping street as on a motorway. One is over four times as likely to be involved in a personal-injury accident on a shopping street as on a rural main road. However, for fatal accidents the position is rather different. The chance of being involved in a fatal accident is, of the categories shown, least of all in a shopping street and highest on a rural main road. Consequently shopping streets lead to the highest rate of personal-injury accident, but to the lowest rate of fatal accidents. But a motorway has the lowest rate for personal-injury accidents and a moderate rate for fatal ones; the ordinary rural main road has a very high rate for fatal accidents and a moderate rate for personal injury. It is worthwhile mentioning in this connection that a motorway recently built between London and Birmingham is estimated to have led in its first year to a saving of 30 lives and the prevention of about 900 other casualties. The reason why it saved lives is because it largely replaced rural roads and not urban roads.

At the Laboratory, a great deal of work has been done on the effect on injury accidents of road layout and associated factors such as junction control and road accessories. The usual procedure has been by means of before and after studies. Some of the results are summarized in Tables II and III; these relate to changes which led to a reduction in injury accidents. In some cases, such as minor realignments or widening of fairly long lengths of road in rural areas or alterations to certain types of junction such as the squaring of right-hand splay junctions in rural areas, the changes led to increases in injury accidents.

Reference has already been made to road accessories such as road markings and signs. Other objects such as trees, lamp standards and the like are a common feature on most roads; vehicles collide with these and people who might otherwise escape are killed or injured.

TABLE I

Injury Accidents per 100 million vehicle-miles in Great Britain

	Shopping streets	*Main Roads (mostly rural)*	*Rural Dual Carriageways*	*Motorway*
Fatal injuries	3	14	6	6
All injuries	800	190	159	70

TABLE II

Changes in Road Layout which have Reduced Accidents

Change in road layout	*Per cent reduction in injury accidents*
Improved alignment at road curves	70
Construction of roundabouts	60
Staggering of crossroads	85
Provision of dual carriageways	30
Improved visibility at junctions	30
Improvements to bridges and culverts	70

TABLE III

Changes in Junction Control and Road Accessories which have Reduced Accidents

Change	*Per cent reduction in injury accidents*	
Installation of traffic lights	40	
All red phase at traffic signals	40	
Slow signs	75	To emerging vehicles
Halt signs	80	
Zebra striping of pedestrian crossings	7	To pedestrians over Great Britain as a whole

In a survey of 1,000 people who were killed whilst travelling in a car, nearly one-third were in a car which struck a fixed object which was a permanent feature of the road layout. Lamp standards were reported in 6½ per cent of these fatal accidents, telegraph poles in 4 per cent and trees in 5 per cent. Kerbs or verges accounted for 6½ per cent, walls and hedges for 6 per cent and other features such as traffic and direction signs for 3½ per cent. There is obviously scope for improvement in the use, siting and design of these objects.

Motorway Accidents

The results of a study of just over 500 accidents involving injury or damage that occurred during the first year of operation of Britain's first motorway showed that, in 53 per cent of the accidents, a vehicle ran off the road on to the central reservation or beyond the hard shoulder; in a further 9 per cent of the accidents, a vehicle ran on to the shoulder itself. Forty-three per cent of the accidents involved one vehicle only and in 40 per cent of these, it collided with a fixed object. Overturning of the vehicle occurred in about 30 per cent of the accidents away from terminals or interchanges and in about 50 per cent of the accidents in which a vehicle ran beyond the hard shoulder. Most of the latter were associated with banks or embankments. In rather less than 10 per cent of the accidents, a vehicle crossed the central reservation and ran on to the opposing carriageway but in only 1 in 10 of these did a collision occur with an oncoming vehicle. The implications of the results in terms of the safety features in the design of this class of road are fairly obvious.

Variations in Accident Frequencies

In Great Britain there are, on the average, 20 people killed, 220 seriously injured and nearly 700 slightly injured on the roads each day. But these numbers vary considerably from day to day. In 1959, for example, the number of fatalities per day, varied from 2 to 73, the total number of reported casualties from 402 on January 11 and 408 on January 18 to 1,618 on July 4 and 2,553 on December 24. These variations are related to differences in the amount of travel, changes in weather, seasons of the year, etc. and these will now be considered.

Effect of Season and Day of Week

An analysis of daily casualty totals in Great Britain in 1959 and daily figures of motor vehicle-miles travelled showed that the casualty rate (casualties per million miles travelled) tends to be higher in winter and on Saturdays. The variance of the daily accident rates amounted to 1.81 (giving a standard deviation of 1.3, compared with the mean accident rate of 5.8), but this is reduced to 0.58 if the influence of season and day of week is removed. Thus, just over half of the daily variation in accident rate is due to seasonal or day-of-the-week variations.

Some idea of the importance of the road surface may be gained from the fact that the resurfacing of a number of roads which were slippery in wet

weather reduced wet road accidents by 80 per cent and all road accidents by 45 per cent. However, the resurfacing of a number of roads not known to be slippery when wet has resulted in an increase in accidents of 25 per cent, presumably due to the increase of speed resulting from the improvement of the road surfaces.

Skidding in Accidents

Some indication of the importance of skidding in accidents is given in Table IV which summarizes the results of an analysis of police accident reports of personal-injury accidents for 1958. Just over half of the skidding accidents occurred when the road surface was wet. For want of precise information on the proportion of time or on the mileage travelled by vehicles for which the roads were in the conditions given in Table IV the percentage of accidents involving skidding has been used as a measure of the risk of skidding, and is referred to as the skidding rate. Ice and snow occur relatively infrequently in Britain and the main problem as regards skidding is that which occurs on wet roads; it will be seen from the Table that no less than 27 per cent of all accidents on wet roads involved skidding.

It has been found that skidding accidents on wet roads show a seasonal variation which is closely related to the seasonal variation in frictional coefficient of the road surface. The skidding rate on wet roads has been as much as three or more times higher in summer than in winter. Analysis of information on the age and sex of drivers involved in skidding accidents has shown some differences between the sexes but, for both, the indications are that with increasing age and experience drivers learn to avoid skidding to some extent. It has been found that motor cycles are about 10 times more likely to be involved in personal-injury skidding accidents than are cars. There are some obvious reasons for this, including the greater vulnerability of motor cyclists to injury in the event of an accident and also the difficulties that arise when braking motor cycles in an emergency.

Investigations into the age and engine capacity of cars involved in wet weather skidding accidents showed that, in general, the newer the car and the greater its engine capacity, the higher was its skidding rate. As regards motor cycles of different engine capacities, there was a slight trend towards higher skidding rates for the larger machines; there was an exception, however, in that the rate was highest for scooters; these have an engine capacity of less than 150 cc. Perhaps the small wheels and tyres used on these machines is more conducive to skidding on wet roads than the larger wheels and tyres used on other machines.

As might be expected, most skidding accidents occur at places on the road where drivers are called upon to brake or corner and thus make higher demands than usual on the frictional properties of the surface. Simply by improving the resistance to skidding of the road surface at places where skidding accidents tend to cluster, considerable reductions in accidents have been achieved. It is worth noting that the savings in the cost of accidents each year may be as much as 10 times the cost of treating the road surface.

Effect of Darkness on Accident Frequency

It appears that, other things being equal, the ratio of accidents in darkness to those in daylight is about 1½ to 2 in dry weather and about 3 to 4 in wet weather.

Effect of Weather on Accidents

Road Wetness. Investigations into the way that road wetness affects accident frequency showed, for example, that wetness is associated with an increase in adult pedestrian casualties by 37 per cent in daylight and 130 per cent at night.

Fog. A study of the effect of fog on accidents occurring in the London area indicated that the frequency of personal-injury accidents per vehicle-mile dropped slightly but that accidents only involving damage increased.

Street Lighting and Accidents

The influence of street lighting on accidents has been studied by comparing the accident frequencies occurring on 64 lengths of road before and after the introduction of better lighting.

The Laboratory studies may be summed up as follows:

(*a*) Good modern street lighting reduced the average frequency of injury accidents in darkness by 30 per cent.
(*b*) There was strong evidence that the reduction in pedestrian accidents was greater than the reduction in other types of injury accident.
(*c*) There were no significant differences between the accident reductions for fluorescent, mercury and sodium lighting.
(*d*) The total savings in accident costs on the 64 lengths were more than sufficient to pay for the increases in the capital and running costs of the improved lighting installations.

Factors Concerning Different Road Users

The Motor Cyclist

About one-fifth of these killed on British roads are motor cyclists or their passengers, most of them being young men under 30 years of age. In relation to the numbers on the road, motor cycles are also the greatest source of injury to pedestrians of all ages, particularly older people. A series of accident investigations into motor cycle accidents gave the following conclusions:

(*a*) The personal-injury accident rate of solo motor cycles is about four times and that of motor cycles with sidecars about twice as great as that of cars.
(*b*) The chance of a motor cyclist being killed per mile ridden is about 20 times that of the chance of a car driver being killed.
(*c*) Ninety-seven per cent of the total casualties in collisions between motor cycles and cars or goods vehicles are motor cyclists.
(*d*) The risk of death or injury to a pillion passenger is about 5 per cent higher than the risk to the driver.
(*e*) Motor cyclists with less than 6 months' experience have about twice as many accidents per head and per mile ridden as those with more experience.
(*f*) Most of the motor cyclists who are killed and many of those who are injured receive head injuries.
(*g*) A study of 7,000 accidents to motor cyclists in the London area showed that the risk of injury to the parts of the head covered by a helmet compared with body injury was 30-40 per cent less for those wearing a safety helmet than for those not wearing a helmet. The risk of death or serious injury (due to head injury only) was 20-30 per cent less for those wearing a helmet than for those without.

The Pedestrian.

The pedestrian is probably the most vulnerable of road users and nearly half the people killed in Britain are pedestrians. Nearly four in every five of the pedestrians killed are children under 15 or adults over 60. Ninety per cent of the accidents to pedestrians occur in urban areas, so that the main problem as far as the pedestrian is concerned is to find ways of helping people to cross the road safely in towns. By relating the number of pedestrian casualties at

TABLE IV

Skidding in Personal-Injury Accidents in Great Britain in 1958

Conditions of road surface	*No. of accidents involving skidding*	*Total No. of accidents*	*Percentage of accidents involving skidding*
Dry	12,730	153,740	8
Wet	19,200	71,970	27
Covered with snow or ice	6,190	8,490	73
All conditions	38,120	234,200	16

TABLE V

The Relative Risk to a Pedestrian Crossing the Road at Different Places

Place	*Relative risk*
On zebra striped pedestrian crossing not controlled by lights...	35
At or within 20 yd. of road junction controlled by lights ...	22
Within 50 yd. of zebra striped crossing not controlled by lights	71
Elsewhere	100

several different types of pedestrian crossing and at other places on a number of roads to the corresponding pedestrian flows, the relative risk to pedestrians of crossing the road was assessed, as shown in Table V. The Table suggests that the safest place to cross the road is therefore on zebra striped pedestrian crossings or at light-controlled junctions.

An examination of pedestrian accidents on roads without a footpath showed that it is more than twice as dangerous to walk with one's back to the traffic as it is to walk facing the traffic. Counts of pedestrians showed that two-thirds of them walked with their backs to the traffic.

Accidents to Children

In the United Kingdom, about 50,000 children under the age of 15 years are injured each year in road accidents. Of these, about 700 are killed and 11,000 seriously injured. The casualty rate for children, expressed in terms of casualties per head of the population of different ages, reaches a peak for pedestrian casualties at the age of six; for pedal cyclists the rate increases with age up to the age of 15. Detailed analysis of the figure shows that one of the greatest dangers to children is that associated with stationary vehicles. No less than 40 per cent of the child pedestrians who were killed or seriously injured in 1958 were involved in accidents in which they were masked from an oncoming vehicle by a stationary vehicle. Another special danger, particularly to those under four years of age, arises when children are playing near stationary vehicles which then move off. Electrically-propelled vehicles which may move off quickly and quietly are often concerned in this kind of accident, particularly as these vehicles are commonly used for house to house deliveries. Studies of child pedal cycle accidents have indicated that the risk of a child cyclist under 10 years of age becoming a casualty is greater than for the average cyclist. It was found that children who were injured when carried as passengers on pedal cycles frequently caught their foot in the wheel of the machine. About 700 children in one year carried as passengers in motor cars were injured when they fell out of the vehicle because of a door opening.

Accident Proneness

It is commonly believed that some drivers are more prone to have accidents than others and several hundred papers have been published in scientific journals giving the results of investigations into the proneness of drivers to road accidents. In one investigation by the Laboratory on this subject, an analysis was made of 2,600 car insurance policies, some of which had been in force for more than 20 years. One result was that people who were 'claim prone' (i.e. who made more claims than others) could usually be detected after their policy had been in existence for 1-2 years, in the sense that people who made one or more accident claims in their first year, had a claim rate in later years 2 to 3 times that of people who did not claim in their first year. The analysis showed also that the claim rate was greatest at ages near 30 and 60 years, was steady between 40 and 50 years of age and was lowest in youth and old age.

TABLE VI

Estimated Effects of Speed Limits on Accidents in Urban Areas of Various Countries

Country	*Accidents*	*Casualties or personal injury accidents*	*Fatalities or fatal accidents*
Switzerland	—2%	—6%	—21%
Netherlands		—6% (slight)	—10% (Fatal + serious)
Sweden		—8%	—9% (Fatal + serious)
Great Britain		more than —3%	more than —15%
Northern Ireland		—25%	—34% (Fatal + serious)
Federal Republic of Germany	—11%	—18%	—30%
Jersey		—8% (slight)	—39% (Fatal + serious)

TABLE VII

Effect of Speed Limits on Main Roads

Place	*Nature of road*	*Nature of restriction*	*Effects on Accidents*
France	Main	80 km/h in 1958 90 km/h in 1959	Reduction of 5 to 30%
Germany	Autobahn	100 km/h	Fatalities —68% Injuries —38% accidents —30%
Britain	Arterial	40 mile/h	Fatal and serious accidents —30% personal injury accidents —20%
Britain	Main, through villages	30 mile/h	Personal injury accidents —10% (not significant)

Alcohol and Road Accidents

According to the national statistics of personal-injury accidents, about 1 per cent of all casualties and 2 per cent of all fatalities on the roads (in 1954) were due at least partly to drink or drugs. There are reasons for believing that these figures represent a considerable underestimate of the true position. Detailed examination of the records of 352 fatal accidents in which 376 people had been killed showed that 18 per cent of those killed were in accidents in which at least one of the principal parties was recorded as having been drinking. In 62 per cent of the accidents after 10 p.m., it was found that someone involved had been drinking alcohol. It was also found that the driver who had been drinking tended to be involved relatively more frequently in single-vehicle accidents. A difference was found, too, in the proportion of people killed on the roads on Sundays; this was higher in England than in Scotland and Wales. Sunday is a day on which there are severe restrictions on the sale of alcohol in Scotland and Wales but not in England.

A special investigation was made into the fatal accidents that occurred during Christmas 1959. In England and Wales, 161 people were killed on the roads during the four days of the Christmas period (December 24 to 27 inclusive). Eighty-one (or 50 per cent) deaths were of pedestrians and 70 per cent of the accidents occurred on urban roads. Two factors stand out in the report—the wet weather that prevailed over most of the period—and the high proportion (three times normal) of people concerned in the accidents who had been drinking not long before it occurred. After making reasonable allowances for the road conditions encountered it was concluded that the accident rate during the period, which was nearly double the normal rate for December, might be attributed mainly to the bad weather and the high proportion of people involved in the accidents who had been drinking.

Speed Limits

In Britain before and after studies have been made of accidents on some sections of the main roads near London on which a 40 mile/h speed limit was imposed early in 1958. On the roads that had previously been subject to a 30 mile/h limit, there was no significant change in the accident record but on those roads that formerly had no speed limit, there were 19 per cent fewer accidents (30 per cent fewer fatal and serious injury accidents).

Data for the effects of speed limits in other countries have been analysed at the Laboratory and these results are given in Tables VI and VII.

So far in this paper, the emphasis has been on the statistical analysis of accidents or on investigations into the nature of and factors affecting accidents. Apart from references to the degree of severity of the injuries sustained by the people concerned in the accidents, nothing has been said about the nature of and factors influencing road injuries. With the exception of the pioneer work on motor cyclist head injuries by Sir H. Cairns at Oxford in the 1940's, the main lead in this field has been by workers in the United States.

Research into road accidents with special reference to the nature of the injuries sustained was started at the Laboratory in 1956. Initially, the object of the investigations was to relate injuries to vehicle design so that improvements in vehicle design and appropriate protective devices for vehicle occupants or riders might be suggested, but, in practice, much useful information about road design (including features such as lamp standards, road signs, trees), as well as about the behaviour of road users, has been obtained.

On-the-spot Investigations

On-the-spot accident investigations have been made, with the co-operation of the Police, on roads within about an eight mile radius of the Laboratory. It has been concluded that:

(*a*) Front seats often fail in an accident, either by tearing away from their fixing or by deformation of the seat frame.

(*b*) If drivers are injured, it is usually due to contact with the steering wheel or column; if, however, the steering column is capable of yielding, the chance of the driver sustaining serious injury is less than if the steering column is more rigidly attached to the vehicle.

(*c*) Drivers and passengers sustain head injuries on the vehicle windscreen or roof. If the glass in the windscreen is of the type known as toughened or tempered glass, there seems to be less likelihood of serious injury resulting from an impact than if the glass is laminated. In the sample investigated, injuries due to contact with the facia board were not common.

(*d*) Frontal impacts resulting from a collision with another vehicle or a fixed object such as a lamp standard often result in severe damage to the vehicle and serious injury to the vehicle occupants.

Injury Investigations

Research on injuries sustained in road accidents in Britain has been carried out along several lines. These have included analysis of the national accident statistics and of the medical statistics relating to road casualties, analysis of coroners' reports on people killed in road accidents, and detailed investigations of individual accidents in which full medical particulars of the injuries have been obtained. The results have shown that, for all classes of road user, head injuries are present in about two-thirds of those who are killed and in a large proportion of those who are seriously injured. Table VIII gives some figures obtained from coroners' reports on fatally injured car occupants.

TABLE VIII

Location of injuries that caused or were capable of causing death among motor-car occupants

(From Coroners' reports for England and Wales)

Location	*Percentage of occupants having serious injury to body area shown*	
	Drivers	*Passengers*
Head	57	65
Neck	8	12
Chest	33	18
Abdomen	12	11
Arms	0	0
Legs	2	4

(Since multiple injuries are included, the percentages are not additive)

REFERENCES

ROAD ACCIDENTS 1958. Ministry of Transport, 1960. H.M.S.O.

SMEED, R. J. Road Accident Statistics in relation to road safety activities. Internat. Rd. Saf. Traff. Rev., 1958, 6 (4).

SMEED, R. J. Accident rates. Internat. Rd. Saf. Traff. Rev., 1955, 5 (2).

Road Research 1956. H.M.S.O.

Road Research 1952. H.M.S.O.

GARWOOD, F., and JEFFCOATE, G. O. Some facts about casualties to pedestrians in Great Britain. Z. Verkehrssicherheit, 1958, 4 (5/6), 216-25.

Road Research 1951. Ministry of Transport Committee on Road Safety. Report to the Committee of Transport on Motor Cycle Accidents. H.M.S.O. 1952.

CHANDLER, K. N. and THOMPSON, J. K. L. The effectiveness of present-day crash helmets for motor cyclists. Operat. Res. Quart., 1957, 8 (2), 63-71.

TANNER, J. C. Reduction of accidents by improved street lighting. Lt. & Ltg., 1958, 51 (11), 353-5.

CHRISTIE, A. W. and MOORE, R. L. Street lighting from the point of view of traffic and safety. Publ. Ltg., 1958. 23 (102), 242-51.

Road Research 1958. H.M.S.O.

GILES, C. G., and SABEY, B. E. A note on the problem of 'seasonal variation' in skidding resistance. Proc. 1st Internat. Skid Prevention Conf., 1958, 2, 563-8.

SABEY, B. E. Accident reports as a guide to slippery lengths of road. Rds. & Rd. Constr., 1956, 34 (403), 203-46.

GILES, C. G. The skidding resistance of roads and the requirements of modern traffic. Proc. Instn. civ. Engrs., 1957, 6, 216-42.

STARKS, H. J. H. Road Accidents, On-the-spot investigations by the Road Research Laboratory. Engineering. 1958, 186 (4831), 466-9.

CAIRNS, Sir H. Crash Helmets. Brit. Med. J., 1946. 2 (4470), 322-3.

PIKE, D. F. B. Accidents resulting in injuries to Army motor cyclists. Department of Scientific & Industrial Research, Road Research Technical Paper No. 13, London, 1949. H.M.S.O.

STARKS, H. J. H. Research on injuries sustained in road accidents. Department of Scientific & Industrial Research, Road Research Technical Paper No. 37, London, 1956. H.M.S.O.

GARWOOD, F. and TANNER, J. C. Accident studies before and after road changes. Publ. Wks. munic. Services Congr., 1956.

SMEED, R. J. The influence of speed and speed regulations on traffic flow and accidents. Rds. & Rd. Constr., 1960, 38 (456), 393-7.

NEWBY, R. F. Road Research Laboratory, Research Note No. RN/3933 Accidents on the London-Birmingham Motorway during the first 12 months (unpublished).

JEFFCOATE, G. O. Road Research Laboratory, Research Note No. RN/3361, December 1958. Trends in child casualties from road accidents 1949-58. (Unpublished).

JEFFCOATE, G. O. The importance of alcohol in road accidents. Brit. J. Addict., 1958, 55 (1), 37-46.

Report of the Special Committee of the B.M.A. on the relation of alcohol to road accidents. London, 1960.

Department of Scientific & Industrial Research, Road Research Technical Paper No. 49, London, 1960 Road Accidents—Christmas 1959. H.M.S.O.

SMEED, R. J. Proneness of drivers to road accidents. Nature, London, 1960, 186 (4721), 273-5.

JOHNSON, N. L. and GARWOOD, F. The analysis of the claim records of a motor insurance company. J. Inst. Actu., 1957, 83 (3). 277-94.

Road Research 1958. H.M.S.O.

ACKNOWLEDGMENT

This paper is published by permission of the Director of Road Research.

PRACTICAL TRAFFIC SURVEYS

B. L. ALLEN, B.Sc. (Eng.), A.C.G.I.

At the Traffic Engineering Group at the Institution of Civil Engineers on October 26, an informal discussion was held on Practical Traffic Surveys. The paper prepared by Mr. Allen, Senior Assistant Engineer, Traffic Engineering Department, Chief Engineer's Department, London County Council, is printed below together with a brief report of the discussion.

THIS paper deals with some of the practical considerations involved in the planning of traffic surveys. The field study methods discussed involve the use of simple equipment only and are therefore suitable for use even by small local authorities or organizations with limited resources. The use of more complex and expensive instruments enables data to be collected and analysed more quickly, enables larger samples to be taken during a fixed period and leads to considerable savings in man hours. Where extensive and continuous studies have to be undertaken, the acquisition of the more advanced types of instrument will probably be justified economically.

For intersection problems the information required is:

> Size and classification of flows by direction and type of vehicle, saturation flow, average delay and queue length for each approach, and pedestrian flows.

For studies over an area:

> Origins and destinations, flows, speeds, travel times, and parking characteristics.

In addition suitable maps and plans will be required on which it is desirable to have shown bus stops, taxi stands, limits of permitted parking, traffic islands, signs and markings, etc.

Field Study methods include the following:

(a) Origin and destination surveys

These can be classified as follows:

(i) *Roadside interviews.* Vehicles have to be stopped and the presence of uniformed police is practically essential. One enumerator can conduct 100-150 interviews per hour, depending on the number of questions asked. Not necessary for interviews on all approaches to be on same day.

(ii) *Home interviews.* Expensive, requires detailed planning and extends over a longer period than other methods, but gives most detailed information. Trained personnel required. Suitable only for large conurbations.

(iii) *Observation of registration numbers.* Pair of men, one observing numbers and one writing them down, can record about 500 numbers per hour. A single observer using a tape recorder can improve considerably on this rate, but a time slightly in excess of the period of study is required for transcription. Use of 'signaller's alphabet' eliminates the possibility of mishearing letters from observer or tape recorder. Many observers are required. Travel times can be obtained.

(iv) *Affixing tag or sticker to vehicle, or handing card to driver at entry point to hand in at exit point.* Vehicles have to be stopped once at least, possibly twice. With tag or sticker intermediate check points can be used to determine routes traversed. Travel times can be obtained.

(v) *Posting or handing reply-paid postcards to drivers to complete and return.* If cards are posted, no information is given on traffic originating outside the survey area. If cards are handed to drivers, lower proportion of replies may be expected from drivers residing outside the area. General response may be poor and biased.

None of these methods requires the use of expensive equipment, but in all cases the analysis is considerably facilitated by use of punched-card machines or computers.

(b) Distribution counts at intersections

At simple intersections mixed flows up to 1,200 v.p.h. on each approach can be classified by type and direction by observing their movements and recording them on special forms, using a separate observer for each type of vehicle. If hand tallies are used mixed flows of 2,000 v.p.h. can be recorded.

At roundabouts and complex intersections it is often possible to follow the paths of vehicles sampled at random from an upper-storey window overlooking the intersection.

When direct observation is not possible the registration number method is usually employed. It is sufficient to record three digits and one letter only, as the risk of duplication is much slighter than with an extensive O. & D. Survey. Using tape recorders, 2,000 numbers an hour can be recorded, hence mixed flows up to 3,000 v.p.h. can be recorded if separate observers are used for each type of vehicle, and if speed and placement of vehicles permit registration numbers to be read with facility.

A method which has been used in the United States is to display signs on one approach requesting all drivers to switch on their lights while passing through the intersection.

(c) Saturation flows at signal-controlled intersections

Webster[1] suggested 'counting the number of vehicles discharged from the queue during a representative number of fully saturated green periods and dividing the mean number by the average effective green period assuming

a fixed value of lost time (say, two seconds)'.

$$\text{i.e.} \quad \text{saturation flow (v.p.h.)} = \frac{\text{av. no. of vehicles discharged} \times 3{,}600}{\text{av. green time (secs.)} + \text{amber time (secs.)} - 2}$$

To reduce the uncertainty due to lost time, counting and timing can be delayed to commence when the third or fourth rank of vehicles crosses the stop line and should terminate with a vehicle crossing the stop line before the amber appears. Then

$$\text{saturation flow (v.p.h.)} = \frac{(\text{no. of vehicles counted} - 1) \times 3{,}600}{\text{period of count (in secs.)}}$$

(d) Delay at intersections

Test runs with cars need to be repeated many times to give reasonable accuracy. Results can be obtained more quickly by a stationary observer recording times of sample vehicles between two points.

A simple method is to count, over a period of one hour, all vehicles entering the intersection from the approach, and at half-minute intervals the number of vehicles in the queue. Then

$$\text{av. delay per vehicle (secs.)} = \frac{\text{av. no. of vehicles in queue} \times 3{,}600}{\text{flow on approach (v.p.h.)}}$$

This method can be refined by the use of an electric desk calculator to give a continuous record of numbers of vehicles in the queue. The machine is cleared and set to 'repeat' position. The 'plus' bar is then held down for duration of study and keys depressed corresponding with the number of vehicles in queue. Then

$$\text{av. no. of vehicles in queue} = \frac{\text{lower register reading}}{\text{upper register reading}}$$

Where queues are too long to be totalled continuously a further refinement is possible. At the commencement of the study, the number of vehicles in the queue is counted and the 'plus' bar held down. One observer records fresh arrivals as a running total on the right side of the keyboard and another observer records departures as a running total on the left side of the keyboard. Then

$$n = x + \left(\frac{r - l}{U} \right)$$

where

- n = average number of vehicles in queue
- x = number in queue at start
- r = reading on the right side of lower register
- l = reading on the left side of lower register
- U = reading on the upper register.

The keys remaining depressed on the right side of the keyboard give total arrivals and those on the left side give total departures.

Then the flow on approach (v.p.h.) $= \frac{(\text{arrivals} + \text{departures}) \times 30}{\text{duration of study (mins.)}}$

(e) Flows

An enumerator recording vehicles by strokes on a form can record 1,200 v.p.h. unclassified, 800 v.p.h. classified into three or four types. Using hand tallies, unclassified flows exceeding 5,000 v.p.h. have been recorded exceptionally, but it is better not to exceed 3,000 v.p.h. for accuracy.

With the moving vehicle method[2], flows of 1,000 v.p.h. can be measured and classified on several roads during the same period of study. Average travel times and mean speeds for each type of vehicle can also be obtained. Where speeds are required as well as flows, this method has advantages.

(f) Speed and travel time

For travel times over sections not exceeding 500 ft. in length, having well defined and readily visible limits and no intermediate intersections, the calculator method suggested by Greenshields may be used. The method was mentioned in section (d) and is described in more detail by Guerin[3].

$$\text{Av. travel time (mins.)} = \frac{\text{concentration (vehicles in section)}}{\text{flow (vehicles per minute)}}$$

Over longer distances vehicles can be timed by relaying registration numbers from one station to another by telephone, and this method gives more observations in a given time than test car runs. However, the method gives no indication of location or length of delays.

If test car runs are used, the method suggested by Wardrop and Charlesworth[2] is to be preferred to the 'average' or 'floating' car methods, because it can give classified speeds and flows and is capable of greater accuracy. In congested multi-lane traffic systems, 'floating' car runs are difficult to achieve and 'average' car runs are difficult to judge.

(g) Pedestrian counts

Pedestrians crossing the street are best counted by observers from high vantage points recording pedestrians as they step on to the kerb after crossing the street. Observers have recorded flows of up to 5,000 pedestrians per hour.

Analysis of Surveys

Where the purpose of a survey is to assess priorities for improvements to the existing road network and its system of traffic control, it is useful to assign a standard speed to each type of highway and to compare observed speeds with standard speeds over each section of road.

The U.S. National Committee on Urban Transportation recommend the use of two indices based on this concept, the delay rate and the vehicle delay rate.

$$\text{Delay Rate} = t - t'$$

$$\text{and Vehicle Delay Rate} = \frac{V\ (t - t')}{1{,}000}$$

where

- t = average observed travel time per mile (mins.)
- t′ = travel time per mile at standard speeds (mins.)
- V = peak hour flow (v.p.h.).

The delay rate indicates sections of road which suffer the most delay, and the vehicle delay rate gives an indication of those sections having the greatest economic justification for improvement.

DISCUSSION

The first speaker in the discussion said that it must be remembered that there were traffic surveys of all sizes. There was still much room for smaller scale traffic surveys at intersections over what might be called traffic complexes.

A traffic count was an important part of a traffic survey but it was necessary to survey all the facts, including the physical ones like road widths and position of bus stops and such like. It was also important for whoever was doing the survey on the site or planning it beforehand to have a good look round and survey the area, looking for any special features. It was no good making a survey of an intersection if one did not pick up the people who were dodging it because it was already rather overloaded; once one improved the intersection they might even come back to it. It was necessary to note pedestrian movements; even if no special pedestrian count was to be made, at least there should be a note made of where the general pedestrian traffic movements were.

Another speaker, associated with the London Traffic Survey, said that comprehensive surveys generally included the collection of data on origins and destinations, traffic volumes, speeds, traffic travel times and the like. These were data collection studies to ascertain existing conditions, but to be a practical traffic survey, the scope and the particular method selected for the study must determine the consideration of the objectives of the study, and if the objective was the development of a well balanced and integrated transportation plan for a large urban area, the comprehensive approach was absolutely essential. The collection of origin and destination data must include various forms of field traffic studies, including roadside interviews, home interviews, interviews of commercial vehicle owners, taxi drivers, and so on. Comprehensive surveys included various types of traffic studies designed to suit the particular objectives of the particular study. It was believed that this type of survey, and only this type of survey, provided all the facts needed for objective evaluations, for improving alternatives and for judicious design decision in connection with broad, integrated urban area transportation problems. Admittedly, the cost of such surveys was great when compared with more limited investigations of specialized, localized, problems. On the other hand, the tremendous cost of improvements required by urban areas warranted objective studies of factual data. He did not believe that urban areas could afford not to approach this problem on a comprehensive basis.

(*Concluded on page* 501)

Future Urban Traffic Patterns

From R. Brain, M.Eng., A.M.I.C.E., A.M.I.Mun.E.

MAY I congratulate Mr. Hodgen on his excellent article 'Future Urban Traffic Patterns' which presented so succinctly the overall problem of projection for future traffic flows and the Fratar technique for Proportional Incrementation. I would further agree wholeheartedly with the comment 'One of the pitfalls of traffic studies is the ease with which elaborate studies can be made to produce incorrect results'.

In his paper 'Directional Traffic Surveys', Mr. Whitehead drew attention to the similarity of traffic patterns extending over many years. This is a reasonable assumption for rural roads but I submit that for traffic there is a relationship similar to the Principle of St. Venant in the field of Elasticity, which states that except in the vicinity of a load its distribution has little effect on the stress patterns. Towns are the major loading points of a highway system and within these areas wholesale redevelopments and the drastic broadening of the motor-owning classes are tending to exert profound modifications on internal traffic flows.

During the last 15 years there has been a three-fold increase of traffic both in terms of numbers of vehicles licenced and in total vehicle miles per annum. In the centres of many towns in Britain however, the volumes and traffic patterns have changed little; these have been impressed upon traffic largely by inadequate road capacities and parking facilities, any relief given being immediately swallowed up by increased traffic previously discouraged to the point of complete suppression. Whether such limitations should be perpetuated is a political issue to be decided by the local authority concerned; if such is to be the case, application of the Proportional Incrementation method will certainly tend to enforce existing patterns on future generations. Perhaps the greatest criticism of the Fratar System is that it will be completely insensitive to such operations as the Tottenham Court Road—Gower Street one-way scheme which must have diverted a considerable volume of traffic into the centre of London, only traffic assignments which are functions of travel time being responsive.

Official estimates of projected national traffic flows—as instanced by Drake and Kidd in their paper on 'Planning for Traffic in the Counties'—have been a singularly unfortunate example of Mr. Hodgen's incorrect results. This type of projection is not strictly applicable to the expansion of land-use data as one must think in terms of vehicle use and degrees of ultimate satisfaction of personal motorization for the particular area concerned. Thus established high density 'working class' tenancy houses often exhibit the greatest growth rate and may generate additional traffic for the work trip at a faster rate than that produced by the construction of new low-density private housing on a previously undeveloped site, although corresponding influence on the shopping trip may be negligible. Zonal growth factors are therefore variable with the time of day and need to be suited to the conditions of design, e.g. rush hour, market day, etc.

Department of Civil & Municipal Engineering,
University College, London, W.C.2.

From Robert Hodgen, M.Sc., A.M.I.C.E.

Mr. Brain's letter raises many interesting points. One of these I must hasten to correct. The Fratar method does not perpetuate an existing pattern. It is based upon an existing pattern but will modify it to a greater or lesser extent dependent upon the nature of the predicted growth of the study area. An empirical proof of the validity of the approach was obtained in a comparison of the 1948 and 1955 origin destination surveys of Washington, reported in the reference given with my article.

The importance of the influence of individual schemes on the traffic patterns of a large town is questionable. A careful distinction must be drawn here between the diversion to the new route which is the immediate effect of a new scheme, and the alteration in the patterns of origin and destination which is a much slower process. On the whole, the overall programme of road improvements is unlikely grossly to alter the accessibility of individual areas. There are, of course, specific instances where this is not true and the possibility of such effects should be carefully considered within individual schemes. However, in the common instance the survey and prediction are undertaken to determine what road improvements are necessary and in the absence of any definite proposals an overall and uniform level of improvement would seem to be the most valid basic assumption.

The question of the growth of vehicular traffic to the city centre is in theory totally a political decision. In fact, the improbability of the complete re-organization and redevelopment of our existing city centres fixes very real and quite close limits to the practical political choice. It does not follow, however, that congestion need be allowed to continue as a means of suppression. The development of an adequate policy for parking in the city centre, the maintenance of an adequate level of public transport particularly to the city centre, and the diversion of traffic having no business in the city centre by an adequate system of motor roads form a much more constructive approach. It follows that a differential growth should be assumed for the densely developed areas of the centre and the remainder of the study area. This can very well be accomplished by the Fratar method. Again the assumption is not that the pattern remains unchanged but that the best prediction for the future will be based upon the existing pattern as modified for the predicted effects of differential growth.

47 Victoria Street, London, S.W.1.

Traffic Engineering Group (*Concluded from page* 500).

The home interview methods were quite suitable for urban areas of even 100,000 persons, and possibly less for certain purposes.

It was said by another contributor to the discussion that in some cases the analysis was considerably facilitated by the use of punch card machines or computers, but this method had its snags. The trouble was that a vehicle going from Saxmundham to Bury St. Edmunds could not be punched into a card. One had to code it and then put the information in that code numerically into the card, or use the other form of input into the computer. The result was that there were two stages which invariably had to be done by skilled staff within the office. The overall result was that for a smaller survey it was quite commonly found to be cheaper and took no more time to do it manually.

Another speaker stated the analysis of routes taken by vehicles presented a very difficult problem. Each vehicle travelled by a more or less individual route, and the number of routes between the origin and the destination was very large. If these were analysed the problem was enormous. For research into the accuracy with which traffic could be assigned to alternative routes this should be done, but he doubted whether it should be done in surveys for general purposes.

He went on that it was important to decide how the results of the survey were to be used and analysed before embarking on it, because the information required and the details of the types of vehicle and the classifications used and the kinds of questions asked in a home interview survey all depended entirely on the way in which the results were to be applied, and although one might decide at the end to do something different, one must have a good idea beforehand, in considerable, detail of what one was going to do with the results.

REFERENCES

[1] WEBSTER, F. V. Traffic signal settings, DSIR Road Research Technical Paper No. 39, London, 1958, p. 23.

[2] WARDROP, J. G. and CHARLESWORTH, G. A method of estimating speed and flow of traffic from a moving vehicle. Proc. I.C.E., Part II, Vol. 3, No. 1, February 1954, pp. 158-171.

[3] GREENSHIELDS, B. D., GEORGE, H. P. and GUERIN, N. S., *et al.* Quality and theory of traffic flow, Bureau of Highway Traffic, Yale University, 1961. pp. 69-103.

New Pedestrian Crossing

IT has been clear for some time that in many cases neither the zebra type crossing or the push button operated traffic signal type of pedestrian crossing provided the ideal control system in all cases, so a new system of control has been designed.

Two of the most important points are, firstly, that as the pedestrian has to press a button in order to obtain right-of-way, it will be absolutely clear to the vehicular traffic whether or not a pedestrian requires to cross. Secondly, the use of a traffic signal type of indication to the motorist will mean that the latter will be less likely to fail to give way to pedestrians. The main features of the equipment are flashing and pulsating signals controlling the road traffic, chevron type zebra stripes and pedestrian signals and push buttons.

Vehicle Signals

The vehicle signals are similar to those used with the standard traffic light, but providing only red and amber aspects. Two sets of red/amber signals are provided for each direction. It has been necessary to take steps in the design of the equipment to ensure that these signals will stand out clearly in day time and at night under all conditions.

A modified chevron type of zebra stripe is provided to enable motorists and pedestrians to distinguish the crossing from traffic lights or the standard type of zebra crossing. In addition, each of the signal standards is surmounted by a yellow globe bearing horizontal black bands.

Pedestrian Signal

Pedestrians are provided with an indicator with the legend CROSS in white letters on a black ground, operated by a push-button unit. The indicator reading WAIT is illuminated at appropriate times and shows as white letters on a blue ground. Two faces are provided on each push-button unit. An interesting feature which will be tested on at least one of the installations is the use of a buzzer to indicate to blind persons whether they have right-of-way. If this is successful, its use could be considerably extended.

Sequence of Operations

The sequence of signal lights is summarized in Table I and is described in detail below.

(*a*) With no pedestrian demand for right-of-way, all signal lights are extinguished.

(*b*) Immediately a pedestrian depresses the button a pulsating amber signal is shown to road traffic and the WAIT indicator on the push button unit is illuminated. The pulsating amber is to warn vehicular traffic that a signal change will shortly take place and that they will be required to stop.

(*c*) After a pre-set period (3 to 7 seconds) the amber and WAIT signals are extinguished and vehicular traffic now receives the pulsating red signal. At the same time pedestrians receive the white CROSS signal. Vehicular traffic must now stop and pedestrians may cross.

(*d*) After a pre-set period (3 to 7 seconds) the pulsating red signal is extinguished and vehicular traffic receives a flashing amber signal. At the same time the white CROSS signal commences to flash at the rate of 90 flashes per minute. During this period pedestrians still have right-of-way if on the crossing, but motorists may proceed if the crossing is clear.

(*e*) After a pre-set period (3 to 13 seconds) the rate of flashing is increased to 180 per minute to indicate that the pedestrian right-of-way is nearly ended. This increased rate of flashing continues for 5 seconds.

(*f*) All signals are now extinguished for a pre-set period (20 to 65 seconds). This is known as the vehicle precedence period and although any pedestrian demand is stored until it has expired, vehicles retain the right-of-way until this time. This is to ensure that during heavy pedestrian traffic the vehicles will be allowed to clear. Operation of the pedestrian push-button during the vehicle precedence period causes the WAIT indicator to be illuminated. At the expiry of this period the cycle of operation described above will commence again if there has been a pedestrian demand. Any pedestrian demand after the expiry of the vehicle precedence period will result in an immediate commencement of the cycle of operations.

TABLE I

Interval	*Road Signals*	*Pedestrian Signals*
1	None	None
2	Pulsating Amber	Wait
3	Pulsating Red	Cross
4	Flashing Amber	Flashing Cross
5	Double Flashing Amber	Double Flashing Cross

Summary

It is felt that if the experiment is successful that this new type of pedestrian crossing will make an important contribution towards the safety of the pedestrian.

At first sight, the sequence of signal lights may appear to be unnecessarily complicated but it will be appreciated that each separate condition indicates a definite part of the time cycle. It is considered that these will very soon be distinguished by the motorists and the pedestrians, even if only subconsciously. There are, in fact, only four basic conditions of signal indications, the same number as used on a normal two-way cross roads with standard traffic signals.

New Publications

(*Concluded from page* 489).

parking spaces, even if all the possibilities in the central area are utilized, and it must therefore be expected that new shopping centres will arise on virgin ground with good road connections; this can be expected to happen at a far lower degree of motorization than in America where the new suburban shopping centres did not begin to appear before the degree of motorization had reached 200 to 300 cars per 1,000 inhabitants'. He also points out that

> If motorists are expected to pay an economic price for parking their cars, the future number of parking spaces is likely to remain, with increasing motorization, far below the figure obtained by simply grossing up the present number in proportion to the increase in population and the increase in the number of cars per 1,000 inhabitants.

He further claims that:

> On the basis of American experience, it is possible to estimate the number of parking spaces in parking garages which could be sold in the central area of European cities, as a function of the degree of motorization.

In his final conclusions, Bendtsen writes that:

> In a realistic assessment of the position, it must be admitted that, with increasing motorization, not all the people who want to use their cars for journeys to the central area of a large city will in fact be able to do so. It is therefore necessary to limit, in some way or other, the influx of cars to the central area during the peak period, and this can presumably be done most effectively by controlling the number of down-town parking spaces.

The reviewer heartily concurs.

N. SEYMER.

CORRECTION

It is very much regretted that an error was made on page 285 of the September issue of this Journal. In the article 'Transportation Planning in the Pittsburgh Region' Figs. 3 and 4 carried a red overlay and these were reversed. The more extensive overlay should, of course, have been on Fig. 3 and *vice versa*.

TRAFFIC ENGINEERS DISCUSS ROAD LIGHTING

by **Granville Berry,** *M.Inst.C.E., M.Inst.Mun.E., A.M.I.W.E., F.I.E.S.*
City Engineer and Surveyor, Coventry.

Fig. 1. Interchanges and approaches to Baltimore Harbour Tunnel.

WHILE there was no session at the World Traffic Engineering Conference at Washington that was specially set aside for the consideration of roadway lighting the important bearing it has on both traffic flow and road accidents clearly emerged at many of the world sessions and at the Annual Meeting of the American Institute of Traffic Engineers.

It was not without its significance on delegates that the Past Presidents Award was presented at the opening session of the I.T.E. to Donald Cleveland of Texas for a paper on 'Driver Tension and Rural Intersection Illumination' in which he showed conclusively that lighting at intersections greatly reduces fatigue and tension and increases the comfort of night driving. Roadway illumination he claimed is one of the engineer's most important tools, as it provides for the special problem of seeing after dark and in experiments carried out it was found that the illuminated intersection produces only 80 per cent as many 'tension responses' as does the unlighted intersection. In fact, it is considered that highway intersections are the most critical points in a road system and the Texas Transportation Institute is conducting further studies to determine the effects of various types of intersectional illumination and signing on safety, comfort and operational characteristics.

P. Lefevre, Chief Engineer (Roads & Bridges) of the Belgian Ministry of Public Works told delegates that in

'HELION'
POST-TOP LANTERN
For town centre and main road lighting, using 2 or 3 x 250/400 watt MBF/U or 3 x 140 watt sodium lamps.

Shown on these pages are some of the more recently developed lanterns of Revo Street Lighting research. Each has been designed to do a specific job with the utmost efficiency and still retain a high aesthetic standard.

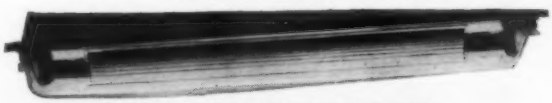
'SOLUMBRA'
POST-TOP LANTERN
For side road lighting, using 100/200 watt tungsten or 80/125 watt MB/U or MBF/U.

REVO ELECTRIC

COMPLETE STREET LIGHTING

HORIZON SIDE-ENTRY LANTERN
For main road lighting using 250/400 watt MBF/U Colour Corrected or MA/V tubular Mercury lamps.

HYPERION' SIDE-ENTRY LANTERN
For main road lighting using 200 watt Sodium lamps of the linear or integral type.



'HORIZON-MAJOR' SIDE-ENTRY LANTERN
For main road lighting using 250/400 watt MBF/U Colour Corrected or MA/V tubular Mercury lamps. Control gear housed in lantern body.

HALYCON' SIDE-ENTRY LANTERN
For main road lighting, using two or three 5 ft. 80 watt MCF/U tubular Fluorescent lamps.

SERVICE LIGHTING

Shown here are some of the more recently developed lanterns of Revo Street Lighting research. Each has been designed to do a specific job with the utmost efficiency and still retain a high aesthetic standard.

BUT Revo engineers and designers can do much more than that. Complete lighting schemes are prepared which take into consideration type of road, volume of traffic, position and type of buildings and trees and local amenities. Proposals are made regarding spacing and location of columns, type of lantern and lamp and mounting height. Fully trained teams are then available to make the entire installation if required.

REVO ELECTRIC CO. LTD., TIPTON, STAFFORDSHIRE

A Duport Company famous for cookers, fires, fluorescent and industrial light fittings, street lighting, switch and fusegear, etc.

W&W 88

Fig. 2. Philadelphia, old lighting.

Fig. 3. Philadelphia, new lighting.

Belgium the standard of lighting has increased considerably in the last three years on roads in urban areas and that all intersections are now to be lighted where the accident rate reaches 12 or more accidents a year. Lighting is being installed on all roads that carry over 10,000 vehicles a day and more than 700 kilometres (440 miles) of traffic roads are to be lighted during the next five years. On well lit roads the accident reduction is about 20 per cent.

On the value of road lighting in reducing road accidents there was unanimous agreement by speakers from France, Italy, the Netherlands, Great Britain and the United States and, in some cases, not only has the lighting paid for itself in accident reduction but also additional benefits have arisen as a result of the transfer of some traffic from day to night that has taken place.

Baltimore's Traffic Engineer, Henry Barnes, said that eliminating some 8,000 gas lamps had also appreciably reduced fatal accidents at night.

In his general report Charles Noble of New Jersey claimed that the guiding principles in the design of interchanges should include the provision of maximum day and night visibility and (speaking of speed change lanes on freeways) that the visibility of the lanes should be of equal or superior quality to the main freeway otherwise motorists would shun them.

In California, according to Karl Moskowitz of the California Department of Highways, a study of freeway fatal accidents for the three years 1957-59 showed that 37 per cent of fatal accidents occurred between midnight and 5 a.m. while only 5 per cent of the travel occurred during these hours—the rate per vehicle-mile being 17 times as high during those hours as it was between 7 a.m. and 6 p.m. In 1960 statistics had proved much the same and 35 per cent of fatalities occurred between midnight and 5 a.m. with 31 per cent during other hours of darkness.

In the British contribution on Street Lighting & Accidents, Dr. R. J. Smeed, the Deputy Director of the Road Research Laboratory (Traffic & Safety), also showed that night accidents could be reduced by the provision of a high standard of lighting on important traffic routes, and the extent of its influence on accidents was summarized in the paper submitted by Dr. H. J. H. Starks, Dr. F. Garwood, Dr. G. O. Jeffcoate, and Dr. Smeed which is printed on page 493-8 of this issue.

In the various cities visited following the Washington Conference one had an opportunity of seeing the general standard of lighting and, while some excellent work is being done in re-lighting the roads of Washington and Philadelphia, there is no doubt that the general standard of lighting on British roads is still ahead. Work is, however, well advanced on the revision of their Standard Practice for Roadway Lighting and this will no doubt lead to the adoption of higher standards of lighting.

The complete absence of sodium discharge lighting, and the compulsory use of dipped headlamps at night on the American roads—even where a good standard of lighting exists, may to some extent be responsible for their lighting having lagged behind British and Continental practice and, after experiencing the glare and 'flicker' of opposing headlamps on multi-lane traffic roads, in both urban and rural areas, one is more than ever convinced that lighting engineers in this country have been right in seeking to provide standards of lighting that render the use of headlamps unnecessary.

Fig. 4. Airline Highway interchange, New Orleans, with Union Metal monotube lighting poles.

INDUSTRIAL NEWS and INFORMATION

Car Park Control
Circuits Management Association Limited (The Rank Organization), and Parking Developments Ltd., have co-operated in a trial installation of automatic car park control equipment.

This installation performs entirely automatically the following control functions:

1. 7.30 a.m.—10.30 a.m. Entry 1s. This is intended to apply to all-day parkers. Free exit.
2. 10.30 a.m.—1.30 p.m. Free entry or a charge of 6d. (This choice is manually set, and thereafter operates automatically). Free exit.
3. 1.30 p.m.—11.30 p.m. Entry 6d. Free exit.
4. 10.30 p.m.—7.30 a.m. No entry, free exit.
5. Continuous measurement of capacity of car park. When full, 'Car Park Full' sign is illuminated, and barrier will not allow cars to enter.
6. Continual audit of vehicle movements registered.

In addition to these controls, a key operated manual override switch allows vehicles to be brought into and out of the car park, irrespective of axle count, at any part of the day or night, without payment.

The coin mechanism will take any combination of 3d., 6d. or 1s., allowing charges to be instantly adjusted over a wide range.

T.E.C. 247 for further details

Nautec Corporation
Following recommendations by Traffic Commissioner of New York, T. T. Wiley, and the City Administrator's Office, the Board of Estimate has approved the initial installation of 5,000 of the new Duncan meters for a pilot installation and, if the meters prove their superiority over the present type, the city will likely replace all 60,000 meters now in use. Sometime ago, due to a heavy upswing in parking meter vandalism during the past year and its attendant substantial loss of income, the City Administrator's Office in conjunction with the Department of Traffic undertook a study of parking meters.

As a result of the test on the meters which were offered by various companies for testing purposes, the meter, manufactured by Nautec's Duncan Parking Meter Division was chosen. The British agents for this meter are Hills Patents Ltd.

T.E.C. 248 for further details

The Parcoa Control Barrier

Traffic Speed Signals
A traffic control system, developed by General Motors Research Laboratories in co-operation with Macomb County Road Commission, is being tried out in America to improve traffic flow over suburban and city streets with intersections.

This system has a series of illuminated speed advisory signals, hanging over the centre of the pavement, with numerals 20 in. high. A motorist entering the four mile system at either end, or from any intersection in between, needs only to obey these speed signals which vary from 25 to 45 miles per hour, to make the next traffic signal while it is still green.

For a two-year period the system will be operated by Macomb County Road Commission, but during the first 12 weeks men from the Michigan State Highway Department will make traffic counts along the route. Their surveys are to determine the time savings and what improvement can be made to Mound Road's intersection capacity, which the Traffic Pacer is designed to increase. County traffic engineers intend to evaluate the Traffic Pacer's efficiency in comparison with a conventional progressive traffic control system, now in use on many city and suburban streets, and a non-interconnected system.

In introducing the Traffic Pacer, engineers warned it is not a panacea. Failure to obey the speed advisory signs will clog traffic lanes just as a slow driver can impede traffic flow behind him. An overflow of traffic on to Mound Road will still cause a jam.

T.E.C. 249 for further details

Bulk Cement Feeder
The photograph below shows the arrangement of a bulk cement feeder body, based on the design of the well-known Atkinson's lime spreader. This body, with a capacity of five tons of cement, can be placed on the customer's trailer, preferably drawn by a Fordson tractor slowed by fitting a Howard reduction gearbox so that its forward speed matches the stabilising train. This tractor will also draw the water bowser.

The bulk cement feeder comprises a hopper body into the floor of which is fitted a belt conveyor which feeds cement to the rear into a detachable trough, the rate regulated by a screed-board. A conveyor elevator delivers the

PRESTRESSING STEEL AND REINFORCEMENT

by McCALLS

FABRIC · BARS · TENTOR · BENDING · MACALLOY · DESIGN

McCALL & CO (SHEFFIELD) LTD. McCALLS MACALLOY LIMITED

TEMPLEBOROUGH · SHEFFIELD · ENGLAND · P.O. BOX 41

Telephone: ROTHERHAM 2076 (P.B. Ex 8 lines)

LONDON: SLOANE 0428 *BIRMINGHAM*: ACOCKS GREEN 0229

PORTSMOUTH: COSHAM 78702 *MANCHESTER*: BLACKFRIARS 1018

cement from the trough into the hopper on the Howard cement spreader up to a maximum rate of approximately 1,600 lb. per minute. A single engine mounted on the right hand side of the Atkinson hopper body drives both conveyors.

The conveyor elevator, which is provided with a weatherproof cover, is fitted at its discharge end with a large diameter canvas funnel which, besides preventing the falling cement from being blown about by the wind, ensures that in the event of the conveyor not being directly over the stabilizer hopper the cement will nonetheless be discharged into it.

T.E.C. 250 for further details

Waterproofing Bridges

On the Wolverton railway bridge waterproofing of the bridge deck was carried out in 24 hours without completely halting traffic on the line.

Defects in bridge structures are often caused by rust or chemical action resulting from seepage after rainfall, and it has been found that waterproofing applied at the appropriate stage of construction or reconstruction can prevent leakage from occurring. The Ruberoid system of bridge waterproofing is suitable for all brick, masonry, ferro-concrete, pre-stressed concrete and steel bridge decks, as well as subways, aqueducts, etc. Recent contracts include the Barton High Level Bridge over the Manchester Ship Canal. The system consists of laminations of Pluvex reinforced bitumen sheeting or Ruberoid copper lined bitumen sheeting bonded with Ruberoid Compound and surfaced normally with brindle or quarry tiles. Pluvex reinforced bitumen sheeting has a hessian base which gives it the necessary tensile strength to withstand the vibration and shock caused by heavy and high-speed traffic. Ruberoid copper lined bitumen sheeting consists of a glass fibre base mat impregnated with bitumen and continuous copper core throughout.

T.E.C. 251 for further details

Road Compaction

A completely new roller introduced this year by Thomas Green & Son Ltd. is the 27/30 T.R.V. tandem vibrating roller and this has already been supplied to Austria, Finland, Italy, Jamaica, Holland, Mexico, India and Pakistan in addition to contractors and public works authorities in the home market.

In recent years the trend has been towards the vibrating type of roller and the new T.R.V. is one of a range of vibrators developed by Thomas Green, including hand guided, tandem and trailed models in various nett metal weights from 8 cwt. up to 4 tons. A particular feature of the vibrating rollers, and one common to the complete range, is the method of vibration. This is so designed that it permits the inclusion of a fixed axle which is securely bolted to the side members, thereby creating a basis of immense strength and rigidity, very important where vibrating rollers are concerned.

Notable features of Green's 'Griffin' Rollers are their short wheel base, providing very good manoeuvrability,

The Bulk Cement Feeder introduced by Rotary Hoes Ltd.

large diameter rolls, all with accommodation for sand or water ballast, and a three speed gear box of their own design and manufacture. Their range of machines includes vibrating and pneumatic tyred rollers, and traditional type rollers from ½ to 13 tons which may be employed at any stage of road construction from foundation laying to surface dressing.

T.E.C. 252 for further details

Atlas Copco Service

With the aim of still further improving their service to the civil engineers and contractors, Atlas Copco, the compressed air engineering group, have opened an international technical advice bureau. Manager of this International Division, as it will be called, will be Mr. W. L. Fairless, at present manager of the Cardiff branch of Atlas Copco (Great Britain) Ltd.

This new Division will be able to call on the technical knowledge and experience of both the British company which is at Hemel Hempstead, Herts, and of the Project Department of the parent firm in Stockholm. Civil engineers who need specialized advice on compressed air problems will be able to obtain it quickly on application to the new division.

The main function of the project Department is to provide a consultancy service for clients on any operation which involves employing compressed air. The department is staffed by qualified engineers who devote their time to supplying information and answers to problems arising in any part of the world.

T.E.C. 253 for further details

Heating Hammersmith Flyover

The heating of the road surface of the new Hammersmith Flyover will be by means of approximately 66 miles of heating cables laid in panels and provided by the Panelec Heating Division of British Insulated Callender's Cables Ltd. The Hammersmith Flyover will, it is believed by the makers of the cable, be the first flyover in the world to be completely heated.

T.E.C. 254 for further details

Laying the cables to heat the Hammersmith Flyover.

Please use the prepaid cards for the Reader Information Service. For further details of items mentioned in this journal, complete and return the card to us.

Lighting a Car Park

Light alloy lighting columns, made by Alf'd Miles Ltd., have been incorporated in a unique new car park in Torquay. Probably the only car park in the world providing accommodation for cars, the storage of yachts in winter, harbour stores and workshops, offices for the Harbour Master and Customs Officers and exhibitions if required. Room for about 250 cars has been provided in what is the first stage of a comprehensive programme to provide the Borough with 4,500 additional car parking spaces over a 10-year period.

The choice of lighting columns fell on Miles light alloy structures.

T.E.C. 255 for further details

A Victor miniature fluorescent lantern on an Adastra column.

Pedestrian Way Lighting

New among the outdoor exhibits at the A.P.L.E. Exhibition at Scarborough was an example of pole-mounted miniature fluorescent lighting fittings suitable for area and pedestrian way lighting. Standard Victor fittings, manufactured by Victor Products (Wallsend) Ltd., were mounted on a super Adastra, lightweight sheet steel 12 ft. 6 in. column, but any standard column may be used. Mounting is by means of a simple spigot cap arranged to accept ¾ in. E.T. nipples to accommodate two, three, or four lighting fittings. In the resulting lighting glare and maintenance are both reduced.

T.E.C. 256 for further details

Gowshall Signlite

Shown by Gowshall Ltd. at Scarborough was their new Mark II Signlite—an external sign illuminator which will take either fluorescent or tungsten lighting. This fitting provides, by virtually a twist of the thumb, simple and quick accessibility for re-lamping and maintenance. The interior is removable and completely inter-changeable to allow a ready method of changing over to fluorescent lighting as required.

T.E.C. 257 for further details

Eddison Plant Ltd.

Mr. A. Lockwood has joined the staff of Eddison Plant Ltd. as Representative for the North-Western Area. He will be based at the depot at Beck Lane, Heckmondwike, Yorkshire. (Telephone Heckmondwike 1360). The north-western Area Manager, Mr. R. F. Ferguson retains the overall control of the area from the depot at Ramsbottom in Lancashire.

T.E.C. 258 for further details

Rubber in Roads

A new edition of 'Natural Rubber for Roads—A Review of Research and Experiment', which is Technical Note No. 3 in The Natural Rubber Bureau's series on rubber in road engineering, has just been published. This incorporates extensive revisions and additions.

The effective rubber content is dealt with more fully and the methods now used to determine this are described, while another section deals with what is possibly the most important recent development in the technique of rubberizing roads, a method of adding latex to cut back bitumen. The method depends essentially on the fine dispersion of latex in the fluxing oil prior to mixing with the bulk of the base bitumen at a temperature below which no immediate gelling will occur. Use of the latex method offers a means of considerably reducing the cost of rubberized roads while ensuring maximum effectiveness. Other sections which have been extensively revised and brought up to date are those dealing with surface dressings, pre-mixed materials and rubber in tar.

T.E.C. 259 for further details

Bulkhead Light Fitting

This is a modification of the well known Widerlite fitting made by Holophane Ltd., and accommodates accessories inside it for use with the 50 watt MBF/U lamp. The fitting incorporates a 50 watt elongated choke specially designed for integral mounting with an 8 MFD capacitor and internal wiring to a terminal block mounted behind a heat deflector barrier plate.

The 50 watt MBF/U lamp, with its high efficiency and rated life of 5,000 hours (average light output 1,350 lumens), reduces maintenance costs and combined with the robust design of the prismatic glass Holophane unit provides an economic lighting proposition for a wide variety of applications.

T.E.C. 260 for further details

The Gowshall Signlite.

Drainage Pamphlet

A folder containing comprehensive details on Key perforated pipes for sub-soil drainage has been published by the Key Engineering Co., Ltd. The pipes, which are basically the same as the standard Key pitch fibre drainpipes —conforming with B.S.2760:1956— are available in 8 ft. and 5 ft. lengths in diameters of 3 in., 4 in. and 6 in.

The pipe is perforated in lines at regular intervals along a 120° arc between its horizontal and vertical diameters. The 3 in. pipe has two rows of ⅜ in. diameter holes at 4 in. centres, 120° apart; in the 4 in. pipe the same holes are 6 in. apart; and the 6 in. pipe has the same holes, but in twin rows on each side of the arc.

The leaflet points out that when the pipes are laid with the holes below the horizontal, ground water enters from below and there is no chance of soil passing into the drain and building up a blockage.

Key perforated pipes for draining roadways and land areas are also discussed.

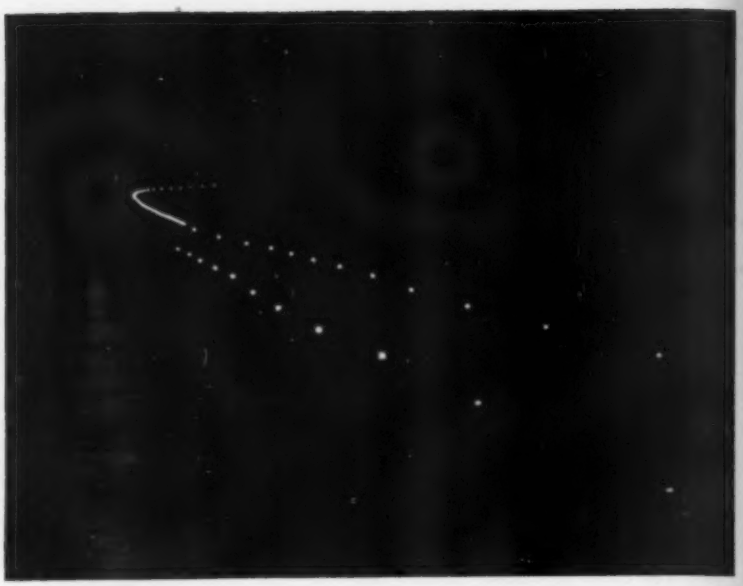
T.E.C. 261 for further details

The modified Widerlite.

TEC724 for further information

CATSEYES

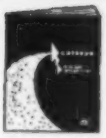
lead the way to ROAD SAFETY



Highway Authorities, Road Safety Organisations and road users all over the world praise "Catseyes". They give clear indication of road direction in all weathers and all lights, and are particularly effective in fog. New methods of installation have now made them even more economical—write for details.

DID YOU KNOW ?

9 yd. spacing of Catseyes (instead of 18 yds.) is authorised on roads subject to fog or mist and on two way roads carrying heavy traffic where there is severe dazzle.



Write today for your copy of the illustrated "Catseye" catalogue.

Registered Trade Mark

—all over the world "CATSEYES" SAVE LIVES

REFLECTING ROADSTUDS LTD., BOOTHTOWN, HALIFAX, ENGLAND

Traffic Engineers !

The all-important TRAFFIC CENSUS can be readily obtained with a

SYX-RRL Vehicle Counter No. 4

Manufactured by :

W. R. SYKES INTERLOCKING SIGNAL CO. LTD.
Voltaire Road, Clapham, London, S.W.4

Sales & Service by :

S.G.E. SIGNALS LIMITED
East Lane, Wembley, Middlesex, England
Telephone: ARNold 4321

TEC725 for further information

Bibliography of Traffic Engineering

The Bibliography recently published in this journal has been published in pamphlet form.

Copies may be obtained from the Editor, price 9d. post free.

For orders of 50 or more, price 6d. per copy post free.